A

TREATISE

ON

AMPUTATIONS OF THE EXTREMITIES

AND

THEIR COMPLICATIONS.

BY

B. A. WATSON, A.M., M.D.,

SURGEON TO THE JERSEY CITY CHARITY HOSPITAL, TO ST. FRANCIS'S, AND TO CHRIST'S HOSPITAL AT JERSEY CITY, N. J.; FELLOW OF THE AMERICAN SURGICAL ASSOCIATION, PERMANENT MEMBER OF THE AMERICAN MEDICAL ASSOCIATION, MEMBER OF THE N. Y. PATHOLOGICAL SOCIETY, MEMBER OF THE N. Y. NEUROLOGICAL SOCIETY, MEMBER OF THE NEW JERSEY MICROSCOPICAL SOCIETY, ETC.

ILLUSTRATED

BY

UPWARDS OF TWO HUNDRED AND FIFTY ENGRAVINGS

AND

TWO FULL-PAGE PLATES.

PHILADELPHIA:
P. BLAKISTON, SON & CO.,
1012 WALNUT STREET.
1885.

Ka

PHILADELPHIA:
COLLINS, PRINTER,
705 Jayne Street.

TO

SIR JOSEPH LISTER, BART., ETC.,

THE FATHER OF ANTISEPTIC SURGERY,

WHOSE LABORS MARK A NEW ERA IN THE TREATMENT OF WOUNDS,

AS A

TOKEN OF SINCERE ADMIRATION FOR HIS PROFESSIONAL GENIUS,

This Work

IS HUMBLY INSCRIBED BY ONE OF HIS DISCIPLES,

THE AUTHOR.

PREFACE.

THE Author's desire to familiarize himself with all the questions pertaining, directly or indirectly, to the subject of this work, had its origin in our late War of the Rebellion, in which he was actively engaged as a medical officer; and consequently he has already been nearly a quarter of a century unceasingly devoted to the study of these topics. These studies have been pursued under favorable circumstances, inasmuch as the Author has had access to a large surgical library in which the works of the great masters of the art and science of surgery have been constantly open to him, as well as the hospital wards of a large city in which terminate a greater number of railroads than in any other in the United States.

Several years of patient investigation satisfied the Author that there was here a demand which ought to be supplied; therefore he was prompted to undertake the preparation of this encyclopædic monograph containing the important facts, theories, and arguments relating to amputations of the extremities and their complications, in order that he might thus facilitate the study of these subjects by placing before medical students and practitioners, in a single volume, much practical knowledge which is not otherwise accessible to them.

It may not be amiss here to call the reader's attention to the fact, that the scope of this work is much broader than might be at first inferred from the title, inasmuch as the complications of

PREFACE.

THE Author's desire to familiarize himself with all the questions pertaining, directly or indirectly, to the subject of this work, had its origin in our late War of the Rebellion, in which he was actively engaged as a medical officer; and consequently he has already been nearly a quarter of a century unceasingly devoted to the study of these topics. These studies have been pursued under favorable circumstances, inasmuch as the Author has had access to a large surgical library in which the works of the great masters of the art and science of surgery have been constantly open to him, as well as the hospital wards of a large city in which terminate a greater number of railroads than in any other in the United States.

Several years of patient investigation satisfied the Author that there was here a demand which ought to be supplied; therefore he was prompted to undertake the preparation of this encyclopædic monograph containing the important facts, theories, and arguments relating to amputations of the extremities and their complications, in order that he might thus facilitate the study of these subjects by placing before medical students and practitioners, in a single volume, much practical knowledge which is not otherwise accessible to them.

It may not be amiss here to call the reader's attention to the fact, that the scope of this work is much broader than might be at first inferred from the title, inasmuch as the complications of

amputation wonnds are essentially the same as those which pertain to any solution of continuity involving the various tissues of the body. It has been his aim to present fairly and fully every topic bearing on amputations and their complications; but it is not for him to determine how far this object has been successfully accomplished.

It may be safely affirmed, however, that this work embraces a very full consideration of all the principal questions pertaining to the performance of amputations and to their after-treatment. In its composition the Author has cited freely from the works of others, both among systematic writers and the contributors to the periodical press of this and other countries. A limited portion of the work has previously appeared in society transactions and other periodical publications of this country; but these papers have been carefully revised, prior to their appearance in their present form, in order to bring them up to the present high standard of surgical literature.

There will be found among the illustrations in this work a considerable number of original wood-cuts; and also a beautifully colored lithograph, while the others have been selected from the following sources: Heath's Operative Surgery, Gant's Science and Practice of Surgery, Hancock's Operative Surgery of the Foot and Ankle-Joint, Emmet's Gynæcology, Gross's System of Surgery, Erichsen's Science and Art of Surgery, Stephen Smith's Operative Surgery, Bryant's Manual for the Practice of Surgery, The American Journal of the Medical Sciences, Bigg's Orthopraxy, Otto and Sons' Catalogue of Surgical Instruments, Arsenal de la Chirurgie Cotemporaine par Gaujot et Spillmann, Traité de Médecine Operatoire par Sédillot et Legouest, Nouveau Dictionnaire de Médecine et de Chirurgie Pratiques, Dictionnaire de Médecine et de Thérapeutique Médicale et Chirurgicale, Troisième Édition, Chirurgie Journalière des

Hopitaux de Paris par Gillette, Chirurgie Antiseptique par Lucas-Championnière, Éléments de Chirurgie Opératoire par Guérin, Mémoire sur une Nouvelle Méthode d'Amputation, etc., par Maisonneuve, Étude sur le Pansement Ouaté par Védrènes, Gazette Médicale de Paris, 1858, Operationen Am Menschlichen Körper mit Abildungen von Günther, Handbuch der Kriegschirurgischen Technik von Esmarch, Normen für die Ablösung grösserer Gleidmassen, etc., von Graefe, Der Schragschnitt von Blasius, etc.

The Author desires to acknowledge in this connection the valuable assistance which has been given him in the completion of this work, especially in the proof-reading, preparation of index, etc., by Dr. F. D. Gray, of Jersey City, N. J.; and also adds, that the mechanical execution is certainly entitled to high commendation. The publishers have spared neither pains nor expense in perfecting it in this respect.

B. A. WATSON.

March 26, 1885.

CONTENTS.

CHAPTER I.

HISTORY OF AMPUTATIONS OF THE EXTREMITIES.

CHAPTER II.

CONDITIONS AFFECTING THE RESULTS OF AMPUTATIONS.

CHAPTER III.

GENERAL CONSIDERATIONS RELATING TO AMPUTATIONS.

CHAPTER IV.

PRELIMINARY CONSIDERATIONS RELATING TO AMPUTATIONS.

CHAPTER V.

AMPUTATIONS OF THE EXTREMITIES.

PAGE

CHAPTER VI.

PRELIMINARY STUDY OF THE TREATMENT OF WOUNDS.

CHAPTER VII.

TREATMENT OF AMPUTATION WOUNDS.

CHAPTER VIII.

SELECTION AND APPLICATION OF ARTIFICIAL LIMBS.

CHAPTER IX.

VARIOUS COMPLICATIONS OF WOUNDS.

CHAPTER X.

PYÆMIA AND SEPTICÆMIA.

CHAPTER XI.

SEPTIC WOUND COMPLICATIONS, ETC.

LIST OF ILLUSTRATIONS.

AMPUTATIONS

AND THEIR

COMPLICATIONS.

CHAPTER I.

A GENERAL HISTORY OF AMPUTATIONS OF THE EXTREMITIES, INCLUDING THE VARIOUS METHODS OF OPERATING, THE MEANS EMPLOYED TO CONTROL HEMORRHAGE, AND THE MANAGEMENT OF THE STUMPS.

LE CLERK informs us that J. H. Schultze, who was a professor at the University of Altdorf, carried his speculations so far into antiquity as to name Adam the first accoucheur by the authoritative voice of necessity; and the former declares that our first parent was not only the first accoucheur, but also the primary physician and surgeon. Human intelligence has prompted men in all ages, climes, and conditions to seek relief from pain and suffering, and their efforts have been greatly aided by human sympathy, but as the success of the treatment must always depend on an accurate acquaintance with the anatomy of the parts and of the existing morbid conditions, and a correct knowledge of the remedial measures, it is therefore highly improbable that the practice of surgery, during the first few centuries, was of such a character as to entitle it to much consideration at this late period. Medical historians have diligently searched through Holy Writ, the tombs of Egypt, the Sanskrit, and the hieroglyphics of different countries and nations, and through all known languages, but with unsatisfactory results, since everywhere its early history is involved in mythology, superstitious practices, and various forms of empiricism.

It is sufficiently established that Egypt was the country in which the art and science of medicine, as well as the other arts and sciences of civilized life, were first cultivated with any degree of success. During the reign of King Psammetichus, who died about six hundred and seventeen years before the Christian era, the primeval darkness began to disappear. In accordance with an ancient custom, the first individuals who made a special study of medicine, and gained a reputation in practice, were raised to the rank of gods. In harmony with this practice, we find that the Egyptians attributed to the deity Isis, the wife of Osiris, the power of causing and of curing disease, and the son of the same goddess was also thought to be gifted in medicine. A chronicler who lived about 261 A. C. mentioned a sovereign who composed some books on anatomy. This sovereign was Athotis, the son of Menes, or, as it is written on the monument, Menai, the first king of Egypt, and the favorite of Memphis. He is reported to have been a physician and an author of some prominence. Independently, however, of this sovereign and this favorite of the gods, the Egyptians revered Theath, Throuth, or Taaut, the Hermes Trismegistus of the Greeks, whom they regarded as the inventor of the arts and sciences. All ancient historians represent him as the friend and confidant of Osiris. He taught the Egyptians the use of writing, and he invented arithmetic, geometry, astronomy, and music. The Egyptians having discovered the art of making paper from the stalks of the papyrus, the knowledge of Taaut was collected in a book entitled *Embre*, or *Scientia Causalitatis*. This book, according to Diodorus, contained the rules of medical science. Herodotus informs us that, during his visit to Egypt, he found many persons engaged in the practice of specialties—a knowledge of which had been handed down from father to son for many generations.

This practice commends itself strongly to our judgment in the absence of a medical library—a source of knowledge on which all modern physicians rely so much, a fountain of wisdom at all times invigorating to the mind, but something wholly unknown to the ancient practitioner. Besides the Egyptian

medical deities, already mentioned, there were Apis, Serapis, and Esmun or Schemin, who were equally revered as divinities. In whatever way these divinities may have first attracted the adoration of the people, it seems clear that the priests, from whom the ancient kings of Egypt were chosen, were the general depositories of knowledge in their times, and ministered equally to the wants of the soul and body. The ancient Hebrew and Greek are known to have borrowed freely from the Egyptian institutions and practices; but it is not necessary for our purpose to follow further the general history of medicine and surgery. The chief object sought to be accomplished in this brief prelude has been to prepare the mind of the reader for a clearer conception of that part of the practice of surgery with which we are interested.

In the absence of ancient history bearing specially on this subject, we are compelled to form our conjectures of what the practice was from the knowledge which we are able to glean from the general history of medicine and surgery. It is certainly rational to suppose that external wounds and injuries received proper treatment at an earlier day than internal lesions and obscure diseases. This statement has been confirmed, in a measure at least, by observation, and therefore a higher standard may be justly claimed for surgery than for medicine during the early ages. In all ages observation and experience have been man's most efficient teachers. The fractured leg could not fail to convey to the mind of an intelligent sufferer, in ancient times even, an important lesson. He would certainly observe that every movement of the injured limb gave rise to pain, and the lesson is quickly learned and reads as follows: "Don't move it." Again, a distorted position of the limb gives rise to severe suffering, which may be endured for a while, but, finally, the sufferer would naturally call on some friend by whose assistance the fractured extremities of the bone might be coaptated, and the patient consequently relieved. The second lesson taught in this case reads thus: "Relieve the deformity by the coaptation of the fractured bones." The bones having been brought into the proper position, the patient remains free from pain until

displacement again occurs. The third lesson taught is: "Prevent a recurrence of the deformity by mechanical appliances."

Schmucker has supposed that amputation of the extremities was first suggested by gangrene, and the separation of the living from the dead parts as accomplished by nature in these cases. Here nature, after much delay and suffering, removes a dead and worthless limb. A desire to improve on this process prompted man to attempt timidly any imitative operation with the knife through the dead tissues. This operation through the dead parts is supposed to have had a very ancient origin; and it was probably practised thousands of years before the birth of Chiron, who lived about the thirteenth century before the Christian era, and who is said to have instructed in medicine the Argonauts and the heroes, who were engaged in the siege of Troy.

Pindar, the great lyric poet of Greece, informs us that Æsculapius, the adopted son and pupil of Chiron the Centaur, employed, among other remedial measures, amputation of the limbs.

We find, in the works of Hippocrates, who lived about 430 B. C., many passages which satisfy us that he was familiar with this operation; in fact, he gives the details for its management with much care, and adds many precautions. He directs the removal at the joints of those portions of the body which are already gangrenous and without sensibility, and where there still remains behind dead tissue he requires its removal as soon as it has fully separated from the living parts and loosened from the bone, which, being now denuded, is allowed to take its own time in separating. In speaking of traumatic gangrene which occurs in connection with fractures, he adds, it may be expected that a rapid separation of the limb will take place, since the bones have already given way. He recommends the prompt removal of the gangrenous parts to prevent further contamination of the body or spread of the disease. Prof. Joseph Flajani has remarked, that if the works of Archagathus and Æsclepiades, who were not only successful surgeons, but also distinguished authors, had not been lost during the dark ages, we might now be able to read a clear description of the operation as it was performed at that period. This opinion is based on

the fact that history asserts that they had not only performed the usual surgical operations, but had also devised and perfected new ones. Here, it is further mentioned, that the operation of laryngotomy, having been devised and first performed by Æsclepiades, has done much towards rendering his name immortal.

The names of these surgeons are closely associated with Roman history. Archagathus, a Peloponnesian, settled at Rome as a practitioner of medicine about two hundred years before the birth of Christ, and is supposed to have been the first who practised medicine as a profession in that ancient city; but, having given offence to its inhabitants, he was finally banished. Asclepiades, who was born in Prusa of Bithynia, flourished at Rome as a surgeon, and as the friend of Cicero, about one hundred years before the birth of Christ.

We now approach an important era in the history of amputations of the extremities which is closely allied in point of time to the birth of Christ, the most important event bearing on Christian civilization and human progress. It should not be forgotten that Aurelius Cornelius Celsus is supposed to have lived under the reign of Augustus, or possibly during a portion of the reigns of Augustus and Tiberius. His writings on amputations are much more explicit and valuable than any others handed down to us from his predecessors. Prior to his time we have no description of any amputation through the living parts, and we know that this operation as originally performed by the ancients was always made through the dead parts, or, as it is sometimes expressed, between the dead and living tissues, but in such a manner as to never disturb the latter. Some authors have supposed that amputations through the living tissues had been performed long before Celsus's time, and this supposition is certainly not without some foundation, as his own writings seem clearly to refer to an old and not a new operation. The style of writing, the description, and the directions severally seem to impress one with the idea that he is dealing with a subject with which he presumes the reader is familiar.

It is therefore probable that the practice of amputating the limb through the living tissues had its origin after the works of

Hippocrates were written and before Celsus's time. This conclusion is founded on the fact that Hippocrates fails to mention such amputations, and further that he shows in so many passages much fear of hemorrhage, a feeling fully shared by the surgeons of his time, in regard to a danger for which there was not yet known a remedy sufficiently potent to successfully combat. The Tourniquet was as yet wholly unknown, and there is no sufficient reason to suppose that either the actual cautery or the ligature had yet been employed in any form for the control of hemorrhage. Furthermore, we find Celsus already familiar with exfoliation of bone, which at that period was probably a constant attendant of amputations, and in order to prevent this accident he recommends the performance of the operation in the following manner:[1] "The incision should be made with a scalpel through the flesh as far as the bone between the healthy and diseased parts so that the joints should be avoided and some of the healthy tissues removed rather than leave any of the diseased. When the bone is reached the sound flesh is to be separated from it, and it is to be cut around so as to expose it somewhat at the point. The bone is then to be cut off with a small saw as near as possible to the sound flesh still adhering to it." Having directed the smoothing off of the bony surfaces, Celsus afterwards, apparently in explanation of the object of his procedure, adds this clause, "and over it we should draw the skin, which, in this method of cures, ought to be lax, so that it should cover the bone as much as possible on all sides."[2]

Flanjani has justly remarked that with good reason we thank Celsus more than any previously known author for his manner of cutting the soft parts which allows the bone to be covered. Previous to his time there is no record of any attempt having been made to cover the bone after an amputation, and strange as it now seems, history shows us that centuries elapsed before the advice of Celsus on this point was adopted. The operation described by Celsus is universally admitted to have been that

[1] Celsus de Medic., libr. vii. c. xxxiii. [2] Ibid.

now known as the circular, and some comparatively modern surgeons have contended, but apparently without sufficient authority, that to this distinguished author belongs also the honor of having first suggested the double incision. A careful examination of his directions ought to satisfy the most skeptical that the skin and soft parts were cut with a single incision; and it is therefore justifiably asserted that by his method the covering of the bone could not have been satisfactorily accomplished; nevertheless, it is certainly evident that he aimed at union by first intention, he having earnestly advocated its great advantages.

The use of the ligature is not mentioned by Celsus in connection with amputations, and his only allusion to hemorrhage is the statement that "patients often die during the operation from the loss of blood."[1] However, in his chapter on wounds, after having mentioned certain measures that might be properly employed to arrest the flow of blood, he condemns the use of others which might excite inflammation in the wound; including, in the category, caustics and other powerful styptics, which are objectionable on account of leaving in the wound a foreign body, and then adds: "But if these fail to arrest the flow, the veins which pour forth the blood should be seized, tied in two places (on either side of the wound), and cut between, so that they may unite and nevertheless have their mouths closed."[2] The language employed here by this distinguished author clearly refers to a wound in a vessel which has penetrated through its wall, but without having severed it. It is, therefore, easily seen that there is in this reference complete absence of any proof of the use of the ligature in cases of amputation.

Galen, who was born A.D. 132, says very little on the subject of amputations, but, like Hippocrates, advises the operation to be made through the dead parts. He was, however, apparently thoroughly acquainted with the measures employed at that time for the control of hemorrhage, and recommends, among other things, placing the finger firmly over the orifice of the bleeding

[1] Ibid. [2] Ibid., libr. v. c. xxvi.

vessel, torsion, and if the bleeding comes from a vein, you should endeavor to restrain it "by means of styptics, or things of an obstruent nature, such as roasted rosin, the fine down of wheaten flour, gypsum, and the like."[1] But if the vessel is an artery, he says one of two things must be done: either a ligature must be applied to it, or it must be cut across. He adds, "we are even obliged sometimes to apply a ligature to large veins and cut them across."

It was during this century that the first distinct allusion was made to the ligature in amputations. The first mention of it is found in the celebrated fragments of the works of Archigenes and Heliodorus preserved in the collection of Nicetas, published by Cocchius (*Chirurgici Græci*, Florent. 1756). "Archigenes begins by stating the circumstances which require recourse to be had to amputation,"[2] and then says: "Before attempting the operation, he recommends us to consider well if the patient's strength will enable him to endure it. The operator must then tie or sew the vessels which pass to the parts; in certain cases a ligature is to be applied round the whole limb, cold water is to be poured upon it, and some are to be bled."[3] Heliodorus, after having mentioned the conditions which render an amputation of the limb necessary, proceeds to the description of it, and adds: "It appears to me better first to divide those parts of the limb where there is least flesh, as on the anterior part of the leg, and then to saw the bone; and I, myself, am in the practice of first applying a ligature above the part of the limb which is to be sawn across, and then of operating in the manner described. In sawing the bone, the plate of the saw ought to be applied even, in order that the sawing of the bones may be even. When the bones are sawed, the other parts which remain undivided are straightway to be cut through with a scalpel, and large pledgets applied along with suitable compresses. External to these, sponges with suitable bandages are to be put on. After

[1] Paulus Ægineta, vol. ii. p. 131, translated by Adams for the Sydenham Society.

[2] Ibid. p. 410.

[3] Ibid. p. 411.

the third or fourth day, when all fear of hemorrhage is over, suppuration is to be promoted by suitable dressings."[1]

History should, therefore, assign to Archigenes the honor of having first employed the ligation of arteries in amputations, but Heliodorus must be permitted to share with him that arising from the practice of passing a cord around the limb above the point where it was to be cut off. Here began the initial practice which led centuries afterwards to the employment of the tourniquet. These appliances were undoubtedly crude, and their application was probably bungling. We know that the ligature employed by these surgeons was a fillet or flat band; that the selection of this band, instead of the slender thread now used, was based on the supposition that small round threads would quickly cut through the coats of the arteries, or through living tissues; and consequently we find the ancients using the flat band instead of a round thread as a suture in closing wounds. A knowledge of these facts enables us to understand why even Heliodorus speaks of amputations above the knee and elbow as extremely dangerous from loss of blood. The same fear continued to control the action of surgeons for many centuries, as is shown by the following:—

Halli Abas, who lived in the tenth century, supplies us with the following instructions: "The operation is to commence with first cutting the skin, and then when the bone of a limb is to be sawn, you must not cut through the whole flesh at once, lest an immoderate discharge of blood take place from the veins and arteries so as to occasion the death of the patient and interrupt the process of sawing the bone; except the flesh of the limb be wasted or putrid. But you ought first to divide that part of the flesh where no great arteries and veins are situated, cutting them down to the bone, which is to be sawn across as quickly as possible, the fleshy parts in the mean time being retracted with a piece of linen, lest the saw should tear them and occasion bleeding and pain; when the bone is sawn across, whatever portion of the flesh remains undivided is to be cut,

[1] Ibid. p. 411.

and then the veins and arteries are to be burned. When the bleeding is stopped a pledget with suitable bandages is to be applied."[1]

Albucasis, who lived towards the end of the eleventh or in the commencement of the twelfth century, urges the following in modification: "When the disease is seated in the hand, he recommends us to amputate at the forearm; when in the forearm, at the elbow; and if the arm itself be affected, he pronounces the case to be hopeless. In like manner, with regard to the lower extremities, he pronounces all cases incurable in which the disease is seated above the knee. In performing the operation he directs us to apply two bandages around the limb, the one above and the other below the place at which it is to be cut off. These bandages are to be pulled, the former upwards and the latter downwards, by two assistants, so as to put the skin upon the stretch; the fleshy parts are then to be divided with a large scalpel down to the bone, which is afterwards to be cut out, or sawed across. . . . . He relates a case from which the timidity of his own practice is rendered very apparent. A person who had a spreading mortification in the foot, cut it off at the ankle-joint himself, and was cured for the time. The disease next attacked the hands, upon which he applied to Albucasis, requesting that he would cut it off in the same manner, but this he refused to do, for fear that the man's strength might not be able to endure the operation. He afterwards learned that the man had cut off his whole hand, and had recovered."[2]

Lest it may be imagined that all knowledge of the use of the ligature in controlling hemorrhage had been lost, although so clearly mentioned at the commencement of the Christian era, I will now refer to the various authors who have spoken of its use and the date of their writings as nearly as it is possible to determine the same.

Aëtius, who lived towards the end of the fifth century, treats on the subject of hemorrhage in about the same terms as Galen,

[1] Ibid. p. 412. [2] Ibid. p. 412.

recommending the ligature under the circumstances mentioned by him.

Paulus Ægineta, who has been supposed by some authors to have lived during the fourth century, while others have brought him down towards the end of the sixth or the beginning of the seventh, alludes to this subject in the following language: "When the vessel is large seize it with a hook, stretch and twist it moderately. When the bleeding is stopped, endeavor if it is a vein to restrain the blood without a ligature by the same medicines. But if it is an artery, one of two things must be done, either apply a ligature around it or cut the vessel asunder, by which means you will restrain the blood. Sometimes, too, we are obliged to apply a ligature to large veins, and also occasionally to cut them asunder transversely."[1]

Palladius, who is supposed to have lived in the seventh century, in his Commentary on the Epidemics of Hippocrates, treating of hemorrhage, says, "we often stop the bleeding by applying a ligature to the divided vessel."[2]

Rhazes, living at the commencement of the tenth century, "makes mention of the cautery, of the application of snow, of the ligature, of styptics, and of cutting the vessel across,"[3] as well as tortion and other measures for the control of hemorrhage.

Avicenna, living at the commencement of the eleventh century, has written much on the subject of hemorrhage and the various measures for controlling it. "He also directs in extreme cases the vessels to be cut across, or a ligature to be applied, namely, a flaxen thread. His description of the process of taking up and tying an artery has quite a modern complexion. He also recommends the application of a compress with tight bandaging when the ligature cannot be applied."[4] It might also be added that the use of a flaxen thread instead of the flat band as a ligature brings us nearer to the successful control of hemorrhage.

[1] Ibid. p. 127.
[2] Ibid. p. 131.
[3] Ibid. p. 132.
[4] Ibid. p. 132.

Averrhoes, living at the commencement of the thirteenth century, like his predecessors, also recommends the use of the ligature.

Guy de Chauliac lived in the middle of the fourteenth century, and recommended the ligature on the authority of Galen and Avicenna.

We have already discussed pretty fully the subject of ligation of the arteries by the ancients, and have shown that the ligature was not only known to them, but was employed to control bleeding even at an early day in cases of amputation and other surgical operations, and further that this knowledge was not lost sight of during the dark ages, but even then continued to be recommended by the authors. This discussion was made apparently necessary by the local claim that was put forward by John Bell and others in behalf of Ambrose Paré. In our subsequent remarks on this subject an effort will be made to show why the use of the ligature for the control of hemorrhage failed to displace the actual cautery and other barbarous means until a comparatively recent date.

Guy de Chauliac was the first to recommend and perform the bloodless amputations. He said it was always better that the limb should fall off than that it should be cut off. Patients in the latter case harbor an ill will against the surgeon, because they think their limbs might have been saved. The first step in this operation was to envelop the whole limb in pitch plaster, and the cord was tied around it at the point where the separation was desired to take place, and beneath this cord was passed a piece of wood of suitable size. The turning of the wood from time to time maintained the cord at the required tightness, arrested the flow of blood below the point of application, and gradually cut through the soft parts. The time required for the performance of this operation was usually about four days. Schaarschmidt's observation in the case of an amputation of a gangrenous limb in 1742 in which there was no hemorrhage, the arteries being perfectly occluded, and the soft parts without sensation, led to much discussion. It was then supposed there was no danger from hemorrhage in this operation.

Waabitz, an Austrian surgeon, in 1872 amputated successfully in this manner fingers, toes, hands, and feet. The principal arguments urged in its favor were complete immunity from hemorrhage, and the fact that some timid persons are more readily persuaded to submit to it than to a cutting operation. During the present century Prof. Dittel, of Vienna, has recommended the employment of the elastic ligature as a substitute for the Spanish twist, or what has been called the turn-stick tourniquet, which was formerly employed in the performance of the bloodless amputations, and therefore Mr. Erichsen[1] characterizes the use of this ligature as "simply a return to mediæval barbarism." Experience has shown that the process is not free even from the danger of hemorrhage, as it has been known to be followed by death from this cause, but unquestionably the greatest danger arises from septic infection.

Another bloodless amputation was recommended by M. Maisonneuve, who published, in *La Gazette Médicale de Paris*, in 1858, a paper entitled "*Mémoire sur une Nouvelle Méthode de l'Amputatione dite Méthode Diaclastique au par Rupture.*" The author of this paper claimed that four-fifths of the deaths following amputations performed in the usual manner arise from accidents inherent to the operation itself; and the most frequent and fatal cause of these unfortunate terminations is due to purulent infection. He asserted that the solutions of continuity made with the ordinary cutting instruments were much more frequently followed by this serious complication than those produced by a paste made with the chloride of zinc, the ligature or the écraseur, which, like subcutaneous wounds, are almost completely protected. He also added that wounds made with scissors are much less liable to give rise to purulent infection than those made with a scalpel. The explanation of these facts is based on the supposed closure of the orifices of the absorbent vessels by the operative procedure before putrefaction takes place. Having briefly stated his prelude, we will now proceed with a condensed description of the operation, the instruments employed, and finally give the conclusions which he reached.

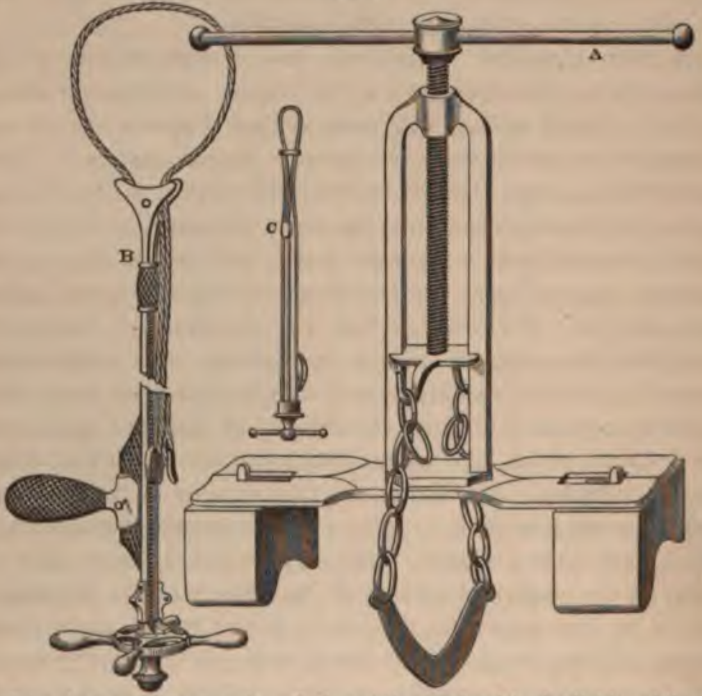
[1] New York Medical Journal, vol. xix. p. 334.

The operation consists of two parts, and should be performed in the following order:—

First, the bone should be broken with the osteo-claste at the point where separation is deemed necessary.

Second, the division of the soft parts is effected by the écraseur about three or four inches below the point where the bone has been fractured, and finally the amputated portion of bone is extracted without the aid of cutting instruments, the object being accomplished by traction and torsion. The instruments required for the performance of this operation are two in number: one is used in fracturing the bone, the other in dividing the soft parts, and both are shown in the following illustration:[1]—

Fig. 1.



A. Osteo-claste and its accessories. *B.* Constriction employed in the division of the soft parts supplied with the handle and a flexible iron loop. *C.* *Serre-nœud de Graefe.*

[1] See La Gazette Médicale de Paris, 1858.

A much more complete description of these instruments will be found in the original article as well as full directions for their use. The author's conclusions are as follows:—

1st. Among the accidents which compromise the success of capital operations is that designated under the name of phlebitis or purulent infection, and is without doubt the most frequent and formidable.

2d. It occurs especially after amputations of the limbs, and generally follows operations performed with cutting instruments.

3d. It almost never follows operations performed by the ligature, caustics, or the écraseur.

4th. This difference depends on the perfectly occluded state of the vascular orifices after the performance of the operation by the above-mentioned means, but the mouths of the vessels are left open when the amputation is performed with cutting instruments.

5th. No successful attempts have been made heretofore to apply the bloodless method to amputation of the limbs in their continuity for want of a convenient power to divide the osseous parts.

6th. The diaclastic method overcomes this difficulty.

7th. The diaclastic method combined with the extemporized ligature simplifies amputations, and renders the performance very easy.

8th. Besides the specific advantage offered by this combination against purulent infection, there are also the following, that it enables the surgeon to operate without assistants, is not followed by loss of blood, and there is no necessity for the application of a ligature to the arteries.

9th. The first applications of the new method have given perfectly satisfactory results. There have been six amputations of the leg and forearm, and all the cases have recovered. Besides the so-called bloodless operations, effected by the means already described, the use of the red-hot knife was strongly recommended by the celebrated Fabricius Hildanus even as late as 1633, while others employed the ivory, iron, or wood knife, which is rendered available by frequently dipping it in

strong nitric acid, and Scultetus, in 1665, described the performance of amputation of the hand by chisel and mallet.

Leonard Botalli, surgeon to Charles IX., King of France, invented in the sixteenth century a machine for amputating the extremities, which has since been designated as the guillotine. This machine consisted essentially of two sharp cutting instruments; one being firmly fastened to a block of wood, and the other, being weighted heavily, was caused to fall from a certain height on the limb lying between these knives, which was instantly knocked off. The cut ends of the vessels were promptly burned; but it is said Botalli did not trouble himself about the bone splinters.

Matthew Gottfried Purmannus, in his *Chirurgia Curiosa*, written as late as 1696, mentions having seen legs removed by two different surgeons by modifications of a barbarous instrument of the middle ages, a sort of guillotine, which, by its great weight and sharpness, cuts at once the skin, flesh, and bones asunder; but he states that it splintered the bone, and, *therefore*, "all things considered, the ancient way of cutting through the flesh with a knife, and through the bone with a saw, is more practicable, safe, and certain."[1] The statement made by Purmannus shows that Botalli's instrument, or some modification of it, was probably in use more than one hundred years.

We will now turn our attention to the various devices employed by surgeons at different times for the control of hemorrhage during amputations.

In the days of Celsus, a method was employed which has been designated "the gripe" (*i. e.*, by assistants grasping the limb), and it will be remembered that the Roman surgeons Archigenes and Heliodorus both recommend the application of a ligature around the limb for the object. The former also directs that the vessels which pass to the part should be tied or sewed, and he further says, that in many cases the whole limb should be firmly bandaged, which will be still more effectual if moistened with cold water.

[1] System of Surgery, ed. by Holmes, vol. v. p. 595.

We also learn from the writings of the Greek, Arabian, and Italian physicians, that an attempt was made to control the flow of blood during amputations by the application of a cord above the point where the cutting was done, but we also find from the same writings that these measures were often insufficient. Fabricius distinctly informs us, that in his youth he saw two patients die from hemorrhage during amputation, notwithstanding the application of this cord. Some surgeons did not seem to be satisfied with one cord, and, we are informed by Schmucker, that Botalli placed three bands firmly around the limb, and performed the operation in the space between the lower two.

Ambrose Paré employed the same number of cords as Botalli, and amputated the limb in the same space.

Prof. Lister says: "As an example of the ordinary practice of the seventeenth century, may be mentioned that of Richard Wiseman, Sergeant-Surgeon to King Charles II. A fillet having been tightly applied, for the threefold purpose of checking hemorrhage, rendering the limb less sensitive by pressure on the nerves, and steadying the soft parts, which were retracted by an assistant, he carried a crooked knife by a single circular sweep down to the bone, which was divided with the saw at the same level, and the bleeding was arrested by the cautery, or some kind of styptic."[1]

A French military surgeon, Morel, at the siege of Besançon, in 1674, was the first to pass beneath the cord, after it had been tied around the limb, a piece of wood: turning this either to the right or left enabled him to increase the power of the apparatus and draw the cord as tightly as he desired. Here originated the tourniquet, which was afterwards described in England by Lawdham, and was also mentioned by Yonge in his work entitled, *Currus Triumphalis e Terebintho*, published in 1679.

It is said by Ravaton that there was found in Morel's effects after his death a drawing of an improved tourniquet similar to Petit's. Petit's improved tourniquet was devised in the early part of the eighteenth century, and is essentially the same as

[1] Ibid. p. 595.

those now in general use. This improved instrument banished from the minds of surgeons all fear of death arising from the loss of blood during the operation except in cases where the amputation was performed so near the trunk as to render the application of the tourniquet impossible. Rapidity of execution was no longer a necessity in amputations, and now surgeons began to think more of neatness and the other important details of the operation.

Prof. Pancoast, of Philadelphia, devised the aortic tourniquet, in 1860, which has been employed with great advantage in cases of amputation at the hip-joint, and Prof. Lister says: "By its means, the flow of blood through all the branches of the internal as well as the external iliac artery being completely arrested, amputation at the hip-joint is divested of the risk of serious hemorrhage, which used to be its most formidable danger."[1]

Mr. R. Davy, in 1877, first suggested and used successfully an instrument which is now called Davy's lever. The lever is passed into the rectum, and by its proper application the iliac vessels are completely compressed, so that only a very slight amount of blood is lost during amputation at the hip-joint. "In comparing Davy's lever with Pancoast's tourniquet, which is usually employed, Mr. Gould held that it had the following advantages: 1. It disturbed the circulation less; 2. It did not interfere with the respiratory movements, nor was it interfered with by them; 3. Its use was not prevented by obesity, rigidity of the abdominal walls, or the existence of abdominal tumors; 4. The pressure required was less; 5. Less liability to injury of viscera and peritoneum; 6. Greater ease and security in application; 7. Greater cheapness and durability; 8. If the lever were not at hand, its place could be more easily supplied."[2] It is now claimed that seven amputations have been performed at the hip-joint in which the bleeding was controlled by this method, and the total amount of blood lost in the seven cases is under fourteen ounces.

The *Lancet* of September 20, 1879, contains a report of a

[1] Ibid. p. 652.

[2] The Lancet, April 26, 1879, p. 597.

method adopted by Mr. Spence, of the Royal Infirmary, for controlling hemorrhage during amputation at the hip-joint, which is as follows: "Mr. Spence, though unwilling to perform any operation, owing to the patient's condition, yet, considering it was his only chance for life, resolved to amputate, using the following method, in order the more completely to control the hemorrhage. The sinuses which were at the outer side of the limb were connected by an incision. The head of the femur was cut down upon, and, with difficulty, owing to the anchylosis which had taken place, was excised. The thigh was then transfixed by a long sharp-pointed steel skewer, three-eighths of an inch in breadth, the point entering at the incision which had just been made, and then taking the course which the knife usually takes in transfixion for the anterior flap. A firm India-rubber band was then twisted tightly around the skewer, including the anterior part of the thigh, much after the method in which vessels are secured by acupressure. Another band was twisted round posteriorly, thus securing the posterior vessels. The operation was then completed by cutting the anterior and posterior flaps. After the vessels were secured the bands were loosened, the skewer removed, and the flaps stitched and dressed. During the excision a small quantity of blood was lost, but during the after-part of the operation scarcely a drop." . . . . .

Another important method for controlling hemorrhage in amputations at the hip-joint has been described by Jordan Lloyd, of Birmingham, England, in the following language: "A strip of black India-rubber bandage about two yards long is to be doubled and passed between the thighs, its centre lying between the tuber ischii of the side to be operated on and the anus. A common calico thigh roller must next be laid lengthwise over the external iliac artery. The ends of the rubber are now to be firmly drawn in a direction upwards and outwards, one in front and one behind, to a point above the centre of the iliac crest of the same side. They must be pulled tight enough to check pulsation in the femoral artery.

"The front part of the band passing across the compress occludes the external iliac, and runs parallel to and above Poupart's ligament. The back half of the band runs across the great sacro-sciatic notch, and, by compressing the vessels passing through it, prevents bleeding from the branches of the internal iliac artery. The ends of the bandage thus tightened must be held by the hand of an assistant placed just above the centre of the iliac crest, the back of the hand being against the surface of the patient's body. It is a good plan to pass the elastic over a slip of wood held in the palm of the hand, so as to diminish the pain of the prolonged pressure of the rubber bandage. In this way an elastic tourniquet is made to encircle one of the innominate bones; checking the whole blood-supply to the lower extremity. The elastic bandage may be secured above the iliac crest in the usual manner with tapes, and may be prevented from slipping downwards by being held with a common roller tied securely over the opposite shoulder. Experience has shown, however, that no mechanical means answer so well as the hand of a trusty assistant. When the band is once properly adjusted, the assistant has only to take care that it does not slip away from the compress or over the tuber ischii. The former is prevented by securing pad and tourniquet together with a stout safety pin; and the latter by keeping the securing hand well above the iliac crest, or even more safely by looping a tape beneath the elastic near the tuber ischii, passing it under the sacrum and leaving it in that position. The solid rubber tourniquet may be used instead of this bandage. I prefer, however, the bandage. The soft parts are less damaged by reason of greater breadth, and it is less likely to roll off the compress placed over the external iliac. The ligature, being altogether above the limb, is out of the way of the surgeon in any operation at or about the hip-joint."[1]

In amputations at the shoulder-joint the circulation in the limb may be controlled by making pressure on the subclavian artery above the clavicle. This may be done with the handle

[1] The Lancet, May 26, 1883, p. 897.

of a large key, or, better still, with Prof. Gross's artery compressor, which he devised in 1856.

Dr. Edwin Moore describes in *The Lancet* of Nov. 29, 1879, "A new method for arresting hemorrhage when amputating at the shoulder-joint." He says: "In cases of amputation at the shoulder-joint that have come under my observation, I have noticed the chief difficulty of the operation to consist in controlling the hemorrhage attending it, necessitating the aid of a quick and competent assistant. I have twice, in performing this operation, adopted a method which renders it almost a bloodless one. I lay a piece of calico bandage across the chest and upper part of the shoulder, and then fix an India-rubber cord or tourniquet around the shoulder over the bandage; this effectually compresses the axillary artery. In order to prevent the India-rubber cord from slipping, an assistant takes both ends of the bandage and holds them across the chest. If called upon to repeat the operation, I would pass a calico bandage under the India-rubber cord, behind as well as in front of the shoulder, then tie the four ends together, and thus dispense with the help of an assistant."

At a meeting of the German Surgical Congress in Berlin, in April, 1873, Prof. Esmarch, of Kiel, announced that by the application of an elastic bandage to the extremities, the limbs could be rendered bloodless, and that by the substitution of a piece of rubber tubing for the tourniquet, the condition of artificial anæmia, produced by the bandage, could be maintained so as to permit operations to be performed on the parts below with even less loss of blood than if performed on the dead body. The reader will undoubtedly recall to mind the employment of the ordinary bandage by the distinguished Roman surgeon Archigenes, but this will not deter him from according to Esmarch that degree of praise to which every one is justly entitled who has so improved an apparatus as to enable the person who employs it to accomplish perfectly the object sought, while it could only be imperfectly accomplished by the original instrument.

Having now passed in review the principal means employed

by surgeons for the control of hemorrhage during amputations of the extremities from the earliest ages to the present time, we will resume the agents used for its prevention after the performance of the operation.

Ambrose Paré, born about the beginning of the sixteenth century, was apprenticed by his father to a barber and surgeon. He finally succeeded in obtaining a position in Hôtel Dieu, where he remained three years, seeing many diseases, and performing many operations. In 1536 he was appointed a master barber-surgeon, and joined in this capacity the army of Marshal René de Mont Jean, which was on the point of starting for Italy. It has been asserted on very strong authority that, at the time when Paré was in Italy, ligation of the arteries was not a very rare operation, and it is probable that he first saw the application made by some Italian surgeon during this campaign. The Italian surgeons had long been familiar with this method of controlling hemorrhage from wounded vessels, and Ferrus had previous to this time minutely described it.

Paré returned from Italy to Paris in 1539, where he remained until 1541; then he again entered the field as a military surgeon, and was thus employed until 1544. It was during this campaign that he first substituted ligation of the arteries for cauterization with a red-hot iron after amputation, although there is reason to believe that he still continued to employ generally the latter. In Paré's Surgery, published in 1552, there is no mention made of tying vessels, but in a later edition, issued in 1564, he first recommends ligation to suppress the bleeding after amputations. In this work he describes two methods of operative procedure. In the first, he directs that the vessels be seized with the artery forceps, drawn forward from the flesh into which it retracts after the amputation, and then firmly tied with a strong double thread. He assures us that nothing is to be feared by taking up the muscles and neighboring parts with the vessels, and is of the opinion that the vessels will thereby sooner heal. This process was found to be defective in practice, since the beak of the forceps was frequently included with the artery and surrounding parts within

the bungling ligature, and the withdrawal of this instrument either loosened or pulled it away. In a subsequent chapter he describes another method in which he employs the needle. He says the needle should be about four inches long, square, and well sharpened, armed with six or eight good threads with which to tie the vessel in the following manner, without the danger of including the beak of the forceps. He introduces the point of the needle one-half inch from the vessel, either on the inner or outer side of the same, then carries it either below or above it, and endeavors to have the points of entrance and exit at the same distance from the artery, including between these points about one inch. The ligature having been introduced is now firmly tied in such a manner that the knot remains in the open mouth of the vessel, and over this is placed a small compress of four or six pieces of linen cloth about one inch square, which protects the knot, and presses it down into the flesh. He further adds that the knot entirely disappears in the mouth of the vessel which has been ligated, and it is completely covered with the adjacent flesh. He also assures us that after this operation not a drop of blood will be seen to flow from the tied artery, but he does not think it necessary to employ the same means to arrest the flow of blood from the small vessels, which can be readily controlled by astringents.

Paré was unquestionably the first French surgeon who either recommended or applied the ligature for the control of hemorrhage, and this innovation brought down on his devoted head the bitter maledictions of the would-be great men of his day. He was compelled in self-defence to write many answers to these malicious attacks, and in this way the arguments in favor of the ligature were clearly set forth, and neither did he fail to produce those against the barbarous cauterizations which had been so long practised. This earnest controversy had the effect of fixing in the professional mind a knowledge of the relative value of the red-hot iron and the ligature as hæmostatic agents. In this case, as in many other instances, the Almighty permitted that demon spirit jealousy to aid in the advancement of science and the confirmation of genius. The men who accused Paré of

ignorance and sought to rob him of his well-earned honors, are now only known to science by this record in which we behold clearly their envious and jealous natures, their disregard of truth, their determined efforts to bring others to their own low level, and therefore they have justly consigned their own names to oblivion while Paré's belongs to science. Prof. John Bell has said of the latter: "He was indefatigable in his profession; he was proud of it; he maintained it against the College of Paris. His high fame descending thus for ages must make you desirous of knowing the real character of the man; and there is no one point upon which his character turns so much as this single invention; for, of all his improvements, this of tying arteries was that of which he was proudest. He says, with the true enthusiam of genius, 'For the good of mankind, and the improvement and honor of surgery, I was inspired by God with this good thought.'"[1]

We have previously shown that Paré is not entitled to the honor of having first recommended the ligature, but he is certainly entitled to the credit of having first brought before the profession its great advantages over the methods previously employed for the control of hemorrhage from the arteries after operations. Some authors have credited him with having devised the curved needle which he employed in the process of ligation, but the same needle had been previously mentioned by the Arabian surgeon Albucasis, and the artery forceps which he employed was mentioned by Ætius. The fact that he labored earnestly and presented unanswerable arguments in favor of ligation cannot be denied; and yet the ligature was not generally employed in surgery until after the lapse of about two hundred years. The veneration which seemed to attach to cauterization because it was known to have been employed by the ancients, and the bigoted opposition made by those who arrogated to themselves the possession of all knowledge, served to keep the fire burning in the brazier that the cautery irons might always be ready to be applied to the quivering human

[1] Principles of Surgery, ed. by Chas. Bell, London, 1826, vol. i. p. 226.

flesh. It was unfortunate for the cause that Paré defended that he was unable to read Latin. Had he known the history of the ligature, he might then have appealed to the prejudices of the profession, which at that time seemed to favor strongly that which was known to be of ancient origin. However, the obstacles heretofore mentioned were not the only ones standing in the way of the unanimous acceptation of the ligature as a substitute for cauterization in amputation.

The ligatures and its application were both faulty. Paré failed to correct the errors into which the ancients had fallen, and continued to use the fillet or band, and to apply it to the artery in essentially the same way as they had done. The ancients greatly feared the possibility of cutting through the coats of an artery in their attempts at ligation, and that the same fear continued to control the action of surgeons even after Paré's time is shown by the remarks of Lawrence Heister, who was born in 1682 and died in 1758. He says: "In case the ligature is very hard twisted, it may easily cut through the coats of the artery, but the ligature being made of a sufficient number of lengths of the shoemaker's threads well waxed together, and made flat, the noose may be drawn moderately tight, and there will not be danger, either of its cutting through the vessel or of a hemorrhage ensuing."[1] The distinguished English surgeon Samuel Sharp, who died in 1765, has given nearly the same directions for making the flat fillet. William Bromfield, another celebrated London surgeon who died in 1792, also recommends the flat ligature. Antonio Scarpa, a celebrated Italian surgeon who was born in 1747 and died in 1823, has recommended the broad ligature, and even cylinders of linen; and others have proposed cylinders of wood, cork, etc. These substances were placed beneath or above the artery, and there the flat ligature or tape was bunglingly tied over it. A little experience in attempting to tie a piece of tape neatly and tightly around a small artery or an artery of any size, we think would soon satisfy

[1] Chirurgical Observations and Cases by William Bromfield, London, 1773, vol. i. p. 160.

the most skeptical surgeon that failure would be the most common result.

The flat ligature and these various practices seem to have been generally employed until after Jones wrote his work entitled, "A Treatise on the Process Employed by Nature in Suppressing Hemorrhage, etc., and on the Use of the Ligature, etc." This book was originally published in Latin in 1803, and translated into English and issued in this language in 1810. This publication had the effect of banishing from the civilized world the use of thick and broad threads, tape, reserve ligatures, cylinders of cork and wood, linen compresses, and all the contrivances which were employed as a security against bleeding, but only served to multiply the chances of its occurrence. Jones demonstrated the superiority of the small round ligature over the flat band, and likewise the great advantage obtained by the direct application of it to the coats of the vessel. These facts had never been previously shown, and it will be remembered that Paré had even claimed that it was advantageous to include in ligation of the vessels some of the surrounding tissues, while LeDran, whose writings made their appearance between 1731 and 1773, says, "that a button of vitriol or alum, applied to the end of the bleeding vessel and properly secured, will restrain the hemorrhage in amputations; but, as accidents have sometimes happened, he prefers the ligature as the securest method; though this he thinks has likewise its inconvenience, as it is almost impossible to take up the artery without including the nerve that accompanies it; in consequence of which sometimes convulsions follow, which make it necessary to cut the ligature."[1] Other authors, writing on this subject, almost universally agree with Le Dran, and therefore deny the correctness of the opinion expressed by Paré on this subject. They call attention particularly to the pain caused by including the nerve with the artery in the ligature, and many on this account condemn entirely the ligation of the vessels. Jones showed that ligation of the vessels should be done with a single thread, and that the ligature should

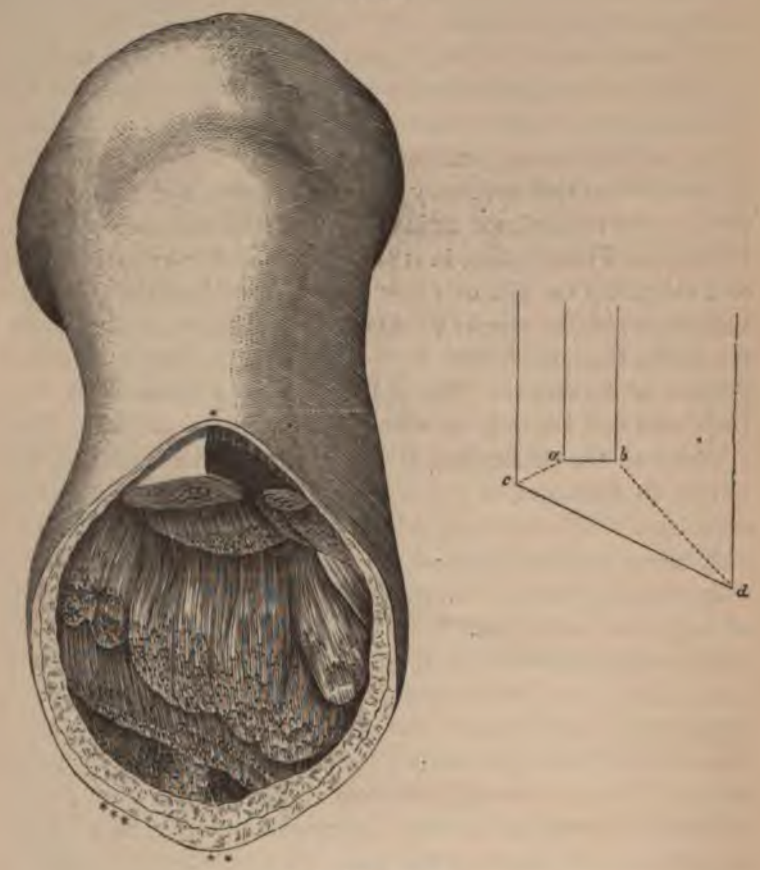
[1] Ibid. p. 158.

be applied directly to the external coat of the artery without including the nerve or any other tissues. Jones, therefore, completed the work in which Paré had engaged so earnestly, and since the beginning of the present century the chief question has been of what material shall the ligature be made, and shall the ends be cut close to the knot or allowed to extend beyond the border of the wound.

William Lawrence, F. R. S., in 1814, recognizing the fact that ligatures are foreign bodies in contact with the surface of the wound and that their presence there must be followed by irritation, inflammation, and suppuration, therefore suggests that the vessels be tied with very fine silk threads, and the ends be cut as close to the knot as is consistent with its security. Dr. Physick, of Philadelphia, in 1814, proposed the animal ligature as a substitute for silk or other vegetable substances. The advantage which he sought to obtain by its use was absorption of the knots, the ends having been cut short according to the suggestion of Lawrence. The spirit of inquiry aroused by Drs. Lawrence and Physick on this subject was sure to bring forth results, and the publication of their experiments soon led Dr. Levert, of Alabama, to try metallic ligatures. He was further stimulated to this action by a knowledge of the fact that metallic balls often remain encapsulated in living bodies many years without doing harm. After repeated trials with various kinds of vegetable, animal, and metallic ligatures the profession has finally settled down to the almost exclusive use of silk and catgut. The former is now generally employed in those cases in which there is no attempt made to procure union by first intention, and the latter commonly used in the treatment of wounds by Prof. Lister's Antiseptic System. In this system of wound treatment the catgut is always carbolized, and the ends of the ligature are cut close to the knot, after which the wound is closed. In those cases in which silk is employed after tying the vessel, one thread is usually cut close to the knot and the other brought out of the wound. The thread which has been brought out of the wound enables the surgeon to withdraw the ligature when it is no longer required to control hemorrhage.

The desire during the present century to rid wounds of every possible source of irritation gave rise to many ingenious inventions intended to take the place of the ligature. The instruments were variously called artery forceps, artery compressors,

Fig. 2.



Single oblique incision.

etc., and it must be admitted that they frequently served very well in skillful hands the purpose for which they were designed; but the introduction of the carbolized catgut ligature has consigned them to oblivion.

We have now brought the history of the ligature down to the present era, but must again retrace our steps and mention certain curious mechanical contrivances which were formerly employed to control hemorrhage after amputation and otherwise expedite the cure of the patient, but which are already almost forgotten.

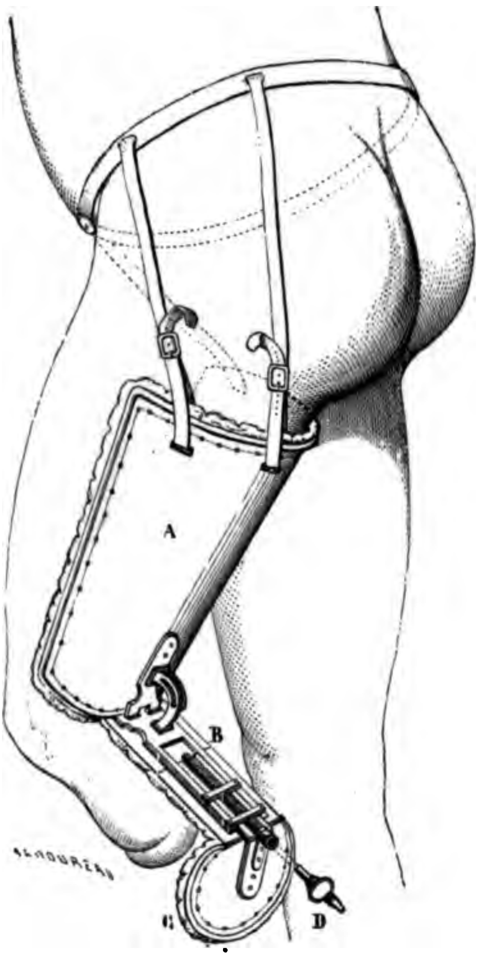
At the end of the seventeenth century Peter Verduin, a surgeon of Amsterdam, made known his method of amputation, and the means by which he controlled the hemorrhage after the operation and supported the flaps. He employed in the leg amputation the single oblique flap which was used by many of the early surgeons. After the operation he washed the wound with warm water, placed the flap over the cut surface, covered the whole stump with styptic medicines, over these applied a bullock's bladder which had been prepared for this purpose by soaking in warm water, over the bladder was placed a concave piece of leather of suitable size, and over the whole was buckled a leather strap in the form of a cross to another which had been placed around the thigh above the knee. This apparatus will be better understood after the examination of the following wood-cut.

Fig 3

Verduin afterwards invented an instrument which he called "Retenaculum," intended to hold the flaps firmly in contact with the parts. This instrument consisted of a concave plate c, which was made either of iron or copper and was applied to the stump

B, by means of the screw D, which was connected with a grooved splint A, in which the thigh rested. The whole apparatus was supported by leather straps, as shown by the following illustra-

Fig. 4.



tion (Fig. 4). This instrument enabled him to maintain pressure sufficient to prevent hemorrhage without the use of ligatures.

Peter Massuet defended Verduin's method on account of the

marvellous rapidity with which the stump healed, and because of the certainty with which the flow of blood was controlled by the pressure over the flaps. Lawrence Heister condemned this method particularly on the ground that the flap was too much irritated by the projection of the bone, thereby giving rise to pain and inflammation. Prof. J. L. Petit, born in 1674 and died in 1750, used an instrument very similar to Verduin's. But all these mechanical contrivances were finally abandoned, because the compression required to control the hemorrhage gave rise in some instances to severe pain, in others to inflammation and gangrene.

There still remain to be mentioned many curious practices which were formerly resorted to for the purpose of controlling hemorrhage, some injurious, others slightly beneficial; but without these the history would certainly be incomplete. The distinguished surgeon John Bell remarks: "Fear and horror led to superstition; and in stopping hemorrhage many superstitions were practised. . . . The iron ore Hematites was so named, because they were persuaded that the very touch of it would suppress bleeding. . . . They tied live toads behind the ears or under the armpits, or to the soles of the feet, or held them in the hand till they grew warm, in order to stop hemorrhages. . . . Michael Mercatus says, that this effect of toads is a truth, which any person, willing to take the trouble, may satisfy himself of, by a very simple experiment; for, 'if you hang the toad around a cock's neck for a day or so, you may then cut off his head, and the neck will not bleed a single drop.' . . . Nor was there anything that could come in competition with it; since nothing could be imagined more unnatural, absurd, and offensive, unless, indeed, it were the moss which grows in a dead man's skull. . . . None of these was more whimsical, nor more degrading to the regular professors of surgery, than that of cutting up a live hen, and thrusting the bleeding member into it. Would you believe that this method of arresting hemorrhages, which had been learned from the hangman, or rather, indeed, from the hangman's wife, was not only mentioned respectfully by so celebrated a person as Platerus,

but actually used by him? 'A vicious horse having bitten off a man's thumb, and all kinds of things had been used to stop the hemorrhagy, but in vain, I, when called, ordered a chicken to be slit up, and ordered him to thrust his thumb into it, and keep it there while the fowl was hot; his hemorrhagy stopped in a minute.' Amulets were worn for the same purpose, and that made from the right ear of an ass was thought to be especially efficacious." The same author farther adds, while speaking of these superstitious practices: "In short they proceeded from folly to obscenity, from obscenity to blasphemy, till they came to profane the most sacred things; and in fact they taught 'it was neither styptics, nor medicines of any kind, but the Devil or our Saviour that did all the good or harm in extraordinary cases.' . . . Their philosophical doctrine of Derivation and Revulsion was not unworthy of those who believed in these charms. In hemorrhages they tried rather to divert the blood than to stop it directly; they applied cupping glasses near the open vessels; put ligatures around the limbs, made strong frictions, or opened a vein in some distant part of the body; they operated from right to left, not diagonally, but according to the direct line of the body. If there were hemorrhages from the left side of the neck, they bled in the left ancle, not in the right; and for hemorrhages from the right side of the head, they bled in the right foot. . . . De Goerter says, 'I have seen this ligature of the little finger practised by an old physician, who assured me, upon his honor, that he had often found it do infinite service, which I firmly believe.'"[1]

Besides the white hot iron there were many other heated substances used in its place, and these have been mentioned as potential cauteries. Boiling oil of turpentine was a favorite application. James Yonge, a distinguished English surgeon, who lived during the seventeenth century, wrote on this subject a book to perpetrate its virtue as a hæmostatic agent entitled *Currus Triumphalis e Terebintho.* "Kettles of boiling turpen-

[1] Jno. Bell, Principles of Surgery, ed. by Chas. Bell, London, 1826. Vol. i. pp. 204–206.

tine were kept in readiness in the cockpit during a battle at sea, and in hospitals where great operations were to be performed."[1] The boiling oils, sulphur, lead, and water were each regarded as valuable auxiliaries to the actual cautery. The stump was immediately after the amputation dipped into these boiling substances for the purpose of controlling the hemorrhage. A case is reported where a surgeon, in his endeavors to improve on Paré's method, had applied the ligature and then proceeded promptly to dip the stump in boiling water. The blue vitriol buttons were also popular with surgeons at one time as a means of controlling hemorrhage. The mode of preparation was as follows: "The vitriol was pounded grossly (not very small), it was wrapped up in a linen rag; this little bundle, like a waistcoat button, was what they called a button of vitriol; and the blood being for a moment suppressed by the tourniquet, this vitriol button was placed carefully upon the mouth of the wounded artery. The tourniquet was let go, after some interval of time, and very slowly. The exuding of the blood dissolved the vitriol slowly. This caustic affected the artery, made an eschar like that of the actual cautery, which fell off after some days. The same precautions of unscrewing the tourniquet slowly, etc., were used in dressing the wound, which was seldom opened up till the fourth or fifth day."[2]

After the long-continued use of cauteries, actual and potential, there sprang up in the minds of surgeons a desire for something more satisfactory. The objections arising from the use of these agents were that the eschars might loosen too soon, and be followed by sudden hemorrhage. "In wounds, the bones and tendons were exposed, the muscles wasted, and the arteries themselves sloughed to a great extent, bleeding as long as the patient's blood retained any color. And in amputation, the flesh was wasted, the bone projected, and the stump was pyramidal, and could not be closed. Is there any wonder that the discovery of some styptic or effectual astringent of the vessels was greatly desired, or that the merest pretender attracted

[1] Ibid. p. 213.

[2] Ibid. p. 213.

notice, or that those few medicines which suppressed hemorrhage, though but in a very imperfect degree, procured for the inventors public rewards? The transition was natural, from corrosive sublimate, caustics, and vitriols, to the milder metallic solutions, which then lost the name of potential cauteries, and were obtruded, in various disguises, under the title of styptics and astringents. The chief styptics have been acid, solutions of vitriol, turpentine, and various solutions of astringent gums in spirits of wine."[1] The virtues claimed for these styptics were truly marvellous. It was said that Digby's "sympathetic powder stanched the blood as effectually, when it was applied to the weapon, as when applied to the wound itself."[2] Rewbell, a German chemist, went to Paris with his styptic, and is said to have so wearied the king with his importunities that finally he was granted permission to apply it to the bleeding surface after the leg had been amputated. He proceeded to make the application, and while thus engaged the patient died in his hands from the hemorrhage which the remedy failed to control. Another vaunted infallible hemostatic agent, called *Styptic cum Regis*, made its appearance during the reign of King Charles II., and the proprietor was finally induced to part with his secret, but not until he had received a princely reward, and then this great remedy was quickly forgotten. In 1750, Mr. Brossard, "a surgeon in Berry, went up to Paris with the hopes of selling a remedy, which he said was perfectly effectual in stopping, not only the hemorrhage of wounds, but that of an amputated limb."[3] While sojourning in Paris he was given an opportunity and succeeded perfectly in controlling the hemorrhages after amputation in three cases. This remedy was the agaric of the oak, a fungus which grows upon the oldest trees. It was cut into small pieces and applied over the mouths of the bleeding vessels; over these pieces were placed compresses, and the whole finally bound on the stump.

Here we find employed a remedial agent which has been classed with the styptics, although its beneficial action was

[1] Ibid. p. 214. [2] Ibid. p. 217. [3] Ibid. p. 219.

undoubtedly due principally to its use as a compress. The success of the remedy depended on the care with which it was applied, and therefore failures often followed its use. The compressed sponge was next recommended by the distinguished surgeon Mr. White, for the same purpose that the agaric had been employed. The remedial power in this case depended on its action as a compress. In this respect it possessed a decided advantage over the agaric, since the degree of pressure exerted in a measure depended on the amount of blood escaping from the vessel.

In the early part of the present century, Mr. Kock, surgeon to the hospital at Munich, rejected ligation as a means of preventing hemorrhage after amputations of the limbs, and employed graduated compresses along the course of the arteries, which were kept in place by a roller bandage. The patient was put to bed after the operation, and watched by an assistant, who, with the hand, made gentle pressure on the stump as long as pulsations are perceived in it.

It has long been customary, in some cases where the surgeon apprehends a return of hemorrhage after an operation, to allow the tourniquet to remain on the limb, either for the purpose of maintaining pressure on the arteries, or in readiness to control any accidental bleeding which may arise. This instrument still continues to be employed in the same manner.

Another class of hæmostatic agents have been recommended under the head of obstruents, among which may be mentioned roasted rosin, fine wheat flour, powdered gypsum, and similar substances which are to be applied on the down of a hare after having been mixed with the white of an egg. "The following simples stop hemorrhages: Aloes, frankincense, manna, Samian earth, the rust of iron, the ashes of burnt wood finely powdered, the dung of an ass or of a horse, a small quantity of bitumen, pomegranate-rind, diphryges, galls, dried myrtle, all kinds of alum, whether crude or burnt, roasted rosin, the bark or green leaves of the vine, and the down of the peels of the plane-tree, more especially when the vessels throw off their crusts."[1]

[1] Paulus Ægineta, vol. ii. p. 129, trans. by Adams.

Many mineral substances, not previously mentioned, have also been used to restrain hemorrhages, among which we might enumerate bismuth, lead, antimony, copper, zinc, arsenic, calcium, etc., but these remedies are no longer employed.

The following hæmostatic agents are still in use, and therefore ought to be mentioned. Prof. James Y. Simpson has recently lauded acupressure, which certainly possesses many advantages over the common silk ligature, but fails to equal the carbolized catgut. Torsion of the small arteries still continues to be practised, and there are yet many advocates for the topical application of heat and cold where the bleeding is confined to the capillary vessels. The galvano-caustic apparatus is still occasionally employed, as well as M. Chaissaignac's écraseur, as preventive hæmostatic remedies, but they are almost unkown in the amputations of the extremities.

Having completed our historical sketch of the measures employed to control hemorrhage during and after amputation from the earliest days to the present time, it now remains for us to resume the historical details of this operation.

Amputations of the extremities were so greatly influenced by the employment of these hæmostatic agents, that a knowledge of these measures was rendered absolutely necessary that we might understand the history of these operations in all their details. Prior to the invention and the employment of the tourniquet, surgeons entered on the performance of these operations with great reluctance. Their minds were filled with the darkest forebodings, before their eyes flitted visions of death, they saw their patient's face blanched from loss of blood, eyes dimmed; and this imaginary vision was commonly realized during the performance of the operation or immediately after its completion. The surgeon having completed the operation, now goes forth while the death cries of the patient are still ringing in his ears, and if he attempts to sleep, these horrible visions reappear in more hateful forms. Was it, therefore, surprising that the ancient surgeons limited themselves generally in amputations to the dead tissues, or even that these operations were seldom performed? The introduction of Morel's tourniquet

inaugurated in this practice a new era. Surgeons now began to boast of the number of amputations which they had performed; and it is greatly to be feared that many limbs were sacrificed to satisfy this rapidly increasing ambition. Schmucker remarks that during his residence in Paris, in 1738, he saw, at the Hôtel Dieu, both thighs amputated on account of simple fractures. This double amputation was performed by a distinguished French surgeon as quickly as possible after the patient's arrival in the hospital, to which he was brought immediately after the receipt of the injury, which had happened not far from the building. During the performance of this operation, the operating surgeon took occasion to remark that it was impossible, in cases like the one before them, to perform the operation with sufficient promptness to prevent the occurrence of fever, inflammation, and gangrene. He evidently thought, as is shown by the celerity of his action, that the sooner the operation was performed the better would be the chances for the recovery of his patient.

These unnecessary amputations were not limited to Paris, or even France, but were advocated and performed by the leading surgeons in every part of Europe. Fortunately for science and suffering humanity, there soon arose some doubts in regard to the propriety of these proceedings; "for, in 1756, the French Academy of Surgery proposed it as the subject for the prize essay in that year, and in consequence of the paper of Faure, an army surgeon, to which they assigned the reward, they decided in favor of delaying the operation whenever practicable, although from the first it was absolutely necessary."[1] In 1761 there was published in the German language a work entitled "J. M. Bilguer's Treatise on the very Rare Employment or the Total Avoidance of Amputation of the Human Extremities." The distinguished author of this work was at that time surgeon-general of the Royal Prussion army, and permitted *no amputation* in that service. His writings on this subject were translated into the French and other languages. There were many French surgeons at this time who were satisfied that amputation of the

[1] Chelius's System of Surgery, trans. by South, vol. i. p. 381.

limbs was performed in cases which would have recovered without this formidable operation, among whom we are able to mention Le Dran, Bagien, and Boucher. Bilguer was ably supported in his opposition to this operation by his distinguished colleague, Schmucker, who inclined to the same doctrines, and has detailed several cases where limbs were not only shattered but actually carried away by balls, yet where a cure followed without amputation. One of his maxims was that it was better for the member to be taken off by gunshot than by the surgeon's knife, as the ball operated on healthy subjects and the knife on a person debilitated by confinement in a hospital. Bilguer, even while opposing amputations in all other cases, admitted their necessity in gangrene, and Schmucker also restricted the performance of this operation to shattered limbs affected with this disease. Bilguer and those who opposed amputations in cases of gunshot wounds brought forward abundant statistics to support their views. They claimed that they were able to save as many lives without amputation in these cases, as were those who still held to the reckless practice which followed the introduction of improved means for the control of hemorrhage. Their opponents asserted, however, that among those reported as cured by Bilguer and his supporters were a much larger number of persons unable to earn a subsistence on account of unserviceable or burdensome limbs than were to be found among those who had been treated by the adherents of the opposing doctrine, and further that the amount of pain suffered by those patients who were so unfortunate as to fall into the hands of Bilguer was far greater than it would have been otherwise.

The question may be asked very naturally what led Bilguer and his co-workers to abandon all cases, except those in which gangrene existed, to nature without operative interference. It has already been suggested that many amputations were performed unnecessarily, and there is abundant proof of the correctness of the statement; but there was still another reason which had much to do with their determination. It must be admitted that the results arising from amputations of the extremities up to this time had been highly unsatisfactory, and consequently

very discouraging to surgeons and patients. We will therefore examine into the causes of these defects.

Before entering on this investigation we ought to recall to mind the fact that from the time of Hippocrates down to the seventeenth century we find complaints made continuously against the sugar-loaf or conical stump which invariably followed amputations during this period. This peculiar stump was due chiefly to two causes: primarily to the manner in which the stump was amputated, and secondarily to the after-treatment. Amputations were performed originally by cutting directly down on the bone and then sawing it through on a level with the soft parts. This method of procedure left the sawed end of the bone without a covering, exposed a large wounded surface to atmospheric influences, and now, as if to make what was already bad still worse, the cautery irons were passed over the entire wounded surface, including the bone as well as the soft parts. This treatment was quickly followed by inflammation, suppuration, septic absorption, and later by exfoliation of the sawed end of bones, unless, as frequently happened, the patient succumbed to the heavy drain on his strength. The recovery from this operation was a tedious and painful process, and the time required to complete the healing varied from six to ten or even eighteen months. There always remained behind a large thin adhering cicatrix, and even in more favorable circumstances, when the integument united over the bone, the covering of skin thus afforded to it did not constitute a good protection. The large cicatrix continued to contract for many months, drawing slowly in this manner the integument of the limb with some of the muscles downwards, forming that peculiar sharp-nosed stump which has been designated as sugar-loaf or conical. In this manner the cicatrix is kept constantly tense, is ever ready on the receipt of the slightest injury to give rise to an ulcer, and these ulcers may continue to annoy the patient for many years, or even during the remainder of his life. Many attempts were made to remedy this evil, which was apparent to surgeons; the soft parts were directed to be drawn strongly up by an assistant while the operator carried the incision down to the bone; metal,

leather, and cloth retractors were employed after the incision had been made in the soft parts before the bone was sawed, for the same object, but with little success. Although Maggi, in 1552, advised that sufficient integument be preserved in amputations to cover the stump, and this suggestion was acted on by Cheselden, in 1720, who drew back the skin after it was cut and then divided the muscles higher up. Cheselden's example was followed by J. L. Petit in 1732, Garengeot 1733, Monroe 1751, and Louis in 1772.

The principal difference in the performance of this operation by different surgeons consisted in the amount of integument preserved, but Alanson performed the operation in such a manner as to preserve a musculo-cutaneous covering for the stump. This method, which has been designated the double incision, still continues to be employed, and may be regarded as an essential part of the circular operation.

Prof. James Symes remarks: "The earlier modes of amputation rendered union by first intention impracticable, and when the operation had been so far improved as to retain the soft parts sufficiently long to meet over the bone, the old system of dressing still continued in use, and the cavity of the stump was stuffed with caddis, as all wounds were in those days healed by the granulating process. Mr. Alanson had the merit of exploding this practice, and introducing light superficial dressings in its stead, which greatly shortened the cure."[1] In the abovementioned facts we behold a condition of things highly favorable to the course pursued by Bilguer, Schmucker, and others, who opposed generally the performance of amputations, and we are even led to regard them as benefactors of the human race.

In order to prevent the projection of the bone after an amputation, and also for the purpose of shortening the time required for the healing of the wound, Lowdham of London, in 1679, first proposed the flap operation, which he promptly put in practice. He was followed by Verduin in 1696, Koenerding 1698, Satorin 1702, Vermole and Ravaton 1739. The popularity of

[1] Principles of Surgery, Phila. 1832, p. 229.

this operation continued to increase, and we find it particularly mentioned in England by White 1760, O'Halloran 1765, Hey 1770, and Alanson 1780, and more recently their example was followed by Larrey, Dupuytren, Lisfranc, Klein, Textor, Beck, Rust, Guthrie, Delevar, and R. Liston. The flaps are cut generally in accordance with the fancy of the operator, although the advantages and disadvantages of the various methods of operative procedure will be considered in a subsequent chapter of this work.

The curved or sickle-shaped knife, with which the ancients performed all amputations, still continued to be employed by all surgeons for the same purpose until 1779, when the straight knife displaced it. Garengeot, in his work entitled "A Treatise of Chirurgical Operations," which was translated into English and published in London 1723, mentions among other instruments required in cases of amputations of the leg the following: "A crooked knife, a small straight knife, not above an inch broad, only with one edge." The use which he makes of these knives is clearly shown in his directions for the performance of the operation, which are as follows: "To perform the third essential thing, which consists in the manner of extirpating the limb, the surgeon covers all the lower part of the leg and the foot with a napkin; and being upon one of his knees, he conveys his right hand under the patient's leg, to take the crooked knife from a servant, placed on the external part: and having the handle of the knife in his hand, he lays the edge of it upon the internal angle of the tibia, as inwardly as he can, and claps the fingers of his left hand upon the back of the same knife, to keep it more even. The operator must hold the knife straight, that is, not more inclined on one side than on the other, and take care not to press hard upon it, when he goes over the spine of the tibia, for fear of turning the edge of it, and so spoiling it for cutting the flesh neatly. When he has cut the skin that covers the tibia he cuts the flesh in the external part of the leg, conveying the knife towards the hinder part of that limb, that he may cut with greater strength the gemini and gastrocnemia; and standing up, he brings up the knife to cut the internal part

of the leg as far as the place where he began; and thus making a circular turn, he cuts the skin, and all the flesh to be found in the circumference of the tibia and the perone, excepting that which lies immediately between the two bones. Some surgeons advise in the next place to convey a dismembering knife into the circular incision, in order to cut the flesh left uncut by the great knife; but when the operator uses a good instrument, and is not too hasty, he has no occasion for the dismembering knife. Now the surgeon must cut the flesh and the vessels that lie between the bones: in order to do it, he takes a small straight knife, or a straight bistoury, which he drives between the two bones, turning the back a little towards the part he designs to preserve; for if he turned the edge that way, he might split the vessels, and he would be at great pains to stop the blood. Before he quits that instrument, he must scrape the periosteum, lying upon the spine of the tibia, and take care always to scrape off the periosteum upon the part that is to be cut off."

Archigenes also speaks of scraping the bone before it is sawed off. It has also been recommended to preserve enough periosteum from that portion of the bone which is removed to cover perfectly the sawed end which remains. This practice was first advised by Walther in 1814, and repeated by Brumenghausen in 1818. Symvonlides of St. Petersburg published in the *Gazette Médicale* in June, 1861, a report of three cases of amputation of the lower third of the leg in which he had preserved the periosteum. It appears, however, from this report that he detached the soft parts from the periosteum and afterwards raised the periosteum from the bone. This method of operative procedure has been justly condemned by Alf. Howze de l'Oulnoit, author of *Étude historique et clinique sur les Amputations Sous-Periostées*, who recommends strongly the preservation of the existing connection between the soft parts and this membrane, so that the nutrition of the parts may be interfered with as little as possible. He claims that by this method of operating

[1] Chirurgical Operations, p. 490.

he shortens the ordinary time required for the healing of the wound, diminishes the size of the cicatrix, and consequently the conicity of the stump.

We have now mentioned the essential historical facts connected with the management of the periosteum in amputations, and this brings our record down to the bone. In regard to the management of the bone we can only reiterate what has already been said on the subject.

Hippocrates left the performance of amputations chiefly to nature. He did not interfere in the separation of the dead from the living tissues in either the soft parts or bones. Celsus directs the bone to be sawn across Archigenes, Heliodorus, and all surgeons since that time, have followed their advice in amputations pertaining to its continuity. The so-called joint amputations as well as Guy de Chauliac's bloodless operation are performed through the articulations.

The earliest after-treatment in cases of amputation which we find mentioned is by Hippocrates. He advises a mild anti-inflammatory treatment, and that the limb should be laid in an elevated position as long as there is any fear of hemorrhage. The only after-treatment mentioned by many of the ancient surgeons, who were in the practice of amputating through the dead tissues, consisted in the application of the actual cautery to the stump. The object of this application was to remove some portion of the remaining necrotic tissues, which was accomplished by their adhering to the irons, to obviate any possible danger from hemorrhage during this process, and it was further supposed that since the bone must necessarily exfoliate this treatment with actual cautery would expedite it.

Celsus is the first to describe an amputation through the living tissues, and he further suggests the closure of the wound after the operation in the following words: "And over it we should draw the skin, which in this method of cure ought to be lax, so that it should cover the bone as nearly as possible on all sides. The part which the skin does not reach must be covered with lint, and above that a sponge squeezed out of vinegar must be tied on the place. The remaining part of the cure

must be the same as I have directed in wounds which are brought to digestion."[1] Besides the previously mentioned treatment the same author in the chapter on wounds adds: "If any patient is not able to bear the strength of vinegar, wine must be made use of; a slight wound is helped by laying on a sponge squeezed even out of cold water. But in whatever way it is put on, it does good no longer than it is moist; therefore it must not be suffered to dry. A wound may be cured without foreign, scarce, and compound medicines. But if one has not confidence in that method he ought to apply a medicine that is composed without such of those things which I mentioned to be proper for bloody wounds."[2] We are not informed in regard to the measures adopted by Celsus for the purpose of holding the integument after it has been drawn over the bone, although he mentions the use of the suture in the following language: "Hence it may now be collected, whether a wound in which the flesh is in one part depending and in another adhering, if it is not yet corrupted, requires a suture or a fibula. . . . . It will be necessary to take up with the needle or the fibula, not only the skin but also some of the flesh to allow it, that it may adhere the more strongly and not break away the skin. Both of them are best done with soft thread, not too much twisted, that it may be the less uneasy to the parts."[3] It seems very probable that this distinguished author employed the fillet to keep the soft parts properly approximated after an amputation, but he fails to mention it when writing on this subject. He was certainly familiar with the art of bandaging, the necessity of cleansing wounds, and the benefit to be derived from the use of hot water in those cases where the wounds had become inflamed. Archigenes mentions the required treatment after amputations in the following language: "Having loosened the band, a cataplasm of leeks, bread, and salt is to be applied to the stump; and the parts about the jaw-bone are to be anointed with cerate of iris and old oil." Heliodorus says: "After the third or fourth

[1] Celsus de Medica, Libr. 7, Cap. 33. [2] Libr. 5, Cap. 26. [3] Ibid.
[4] Paulus Ægineta, trans. by Adams, vol. ii. p. 411.

day, when all fear of hemorrhage is over, suppuration is to be promoted by suitable dressings."[1]

Paulus Ægineta says: "During the first day after the amputation the stump is covered with leeks and salt, but on the second day this dressing is replaced by bread and honey,"[2] but the author fails to mention the length of time which the latter dressing should be continued, or the object which prompted its application."[2] In describing amputation John de Vigo tells us, "the bone must be sawed wtth a keene sawe, and after that it is cut with a sawe, it *must* be cauterized with an actuall cauterie."[3] James Y. Simpson, in his work on Acupressure says: "In the olden times of surgery, when the hemorrhages accompanying operations were arrested only by cauteries and caustics, all thoughts of effecting union by first intention were of course idle and vain; for the existence on the surface of the wounds of the resulting dead sloughs and burnt crusts totally and utterly prevented all chances of primary adhesion. But even after cauterization began to be abandoned for styptics, compression, and deligation, it was with difficulty and distrust that the idea of the union of wounds by primary adhesion began to be entertained, and attempted in cases of amputation by Yonge, Verduin, Sabourin, Vermale, Garengeot, etc."[4]

It should be remembered that Ambrose Paré himself recommends in the first dressing of amputation wounds that the actual cautery be applied to the ends of the bones, because he argues they have been tainted by the saw and the appulse of the air.

Prof. James Y. Simpson in the same work adds: "In the ancient primary dressing of wounds, after they were duly cauterized, stimulating and detersive applications were for the most part immediately applied to them, to promote and hasten their sloughing and 'mundification.' These applications consisted of all possible forms of powders, ointments, liniments, waters, etc., made out of complex farragoes of all possible kinds of sub-

[1] Ibid.
[2] Sprengel's Geschichte des Chirurgie, Band. I. S. 405.
[3] Acupressure, by J. Y. Simpson, p. 16.
[4] Ibid. p. 12.

stances. The substances were chiefly mineral and vegetable; but the animal kingdom also yielded its due quota. For instance, Paré himself specially lauds the oil of whelps as a detergent application to recent wounds, particularly to gunshot wounds. 'This oyle,' says he, 'hath a wonderful force to asswage paine, to bring the wound to suppuration, and cause the falling away of the eschar.' And, in consequence of his praise and publication of it, 'almost all chirurgiens,' he adds, have used and daily doe use it with happy successe.' He tells us further, that 'with much intreaty and expence,' he originally obtained the receipt for it from 'a certaine chirurgien wondrous famous for curing these wounds.' It was made by boiling in four pounds of oil of lilies two new-born 'whelps' (*catellos*) placed alive in the oil, with one pound of earth-worms, and afterwards adding three ounces of Venice turpentine, and one ounce of *aqua vitæ*. Paré had the honesty and courage to publish the receipt for making this and other topical medicines for wounds; and similar receipts were published by some of the older surgeons. But in the professional works of others, the modes of preparing their wound-waters, ointments, etc., were sedulously and systematically concealed, though their alleged virtues were loudly and pompously lauded."[1]

Fabricius Hildanus remarks that surgeons burn the vessels with the actual cautery to control hemorrhage, and also the bone itself, from which fragments have been detached.

Richard Wiseman rejects cauterization and ligates the vessels. After the amputation he draws the flaps together, and to retain them in position he employs either the roller bandage or sutures, giving his preference to the latter, as he believes that without stitching the flaps are more liable to retract and leave the bone uncovered. Having closed the flaps and introduced the sutures, he then applies a wax plaster transversely over the parts, spreads over the whole stump a thick layer of Armenian bolus, meal, pitch, mastich, dragon's blood, and aloes. External to these he applies a beef's bladder, and finally wraps the whole

[1] Ibid. pp. 124, 125.

limb in a roller bandage. 'The above mentioned dressing is removed on the third day, and another takes its place composed of the following ingredients: turpentine, meal-elemi, and the yolk of an egg.

Prof. Renatus James Croissant Garengeot, who was born in 1688 and died 1758, says: "Having thus explained how the amputation of the limbs ought to be made, I proceed to the dressing of the patient; the surgeon must bend the stump, and draw the flesh and the skin about the bones, as much as he can. Afterwards he lays upon the vessels lying between the bones a narrow and very thick compress; the two small dry plagets upon the bones, small square compresses upon the other ligatures, and upon the whole some plagets of different figures, to compress in every part. We might with the same intent lay over those plagets some coarse lint, without any figure of plagets or dozels. 'Tis true, that by such a method we depart from the practice of many surgeons, who chide the servants when they bring plagets that are not neat and in good order; but that regularity of the plagets does not fit so close upon every part as when they are shapeless, and the lint is without any regular order. Surgeons do also commonly use two flaxen plagets, one covered with colophony, and the other with bole Armeniæ, and over these large plagets, covered with astringent powders, they farther lay a hog's bladder. All these remedies are useless, very perplexing, and even hurtful; they are useless, since the lint alone is an astringent and absorbent, which answers all the indications. It is well known, why all these applications are perplexing; and therefore I need not dwell upon it; but it is not improper to know, that these powders are extraneous bodies, which occasion obstructions, inflammations, and sometimes the consequences of these diseases; besides, they retard the suppuration, and stick so close to the circumference of the stump, that 'tis extremely difficult to take them off, as I have often observed, so that the stump bled on all sides after the removing of these astringents. I have seen that operation performed by Mr. Petit, who only uses more plagets, in the manner above mentioned; and on the third day the suppuration was come to a

head, the plagets falling off themselves, without any need of pulling them, as must be done when the plagets are made of flax. After the application of the plagets, that surgeon advises us to use a plaster made like a T, with four heads, covered at the end of those heads with the plaster of Andreas a Cruce, to draw the skin and the flesh over the bones. If I have said that the hair should be shaved before that operation, it is in order to prevent that plaster, which is a powerful agglutinative, from sticking to it, and occasioning pain when it is taken off The surgeon lays over the plaster a square and thick compress, not exceeding the circumference of the stump; he covers it with the double compress made in the form of a Maltese cross; he applies one of the arms of it under the ham, and the middle of the cross passing over the stump, the opposite arm is applied upon the fore and upper part of the leg, etc. Afterwards the surgeon applies the longitudinal compresses, which must not be very broad, to make a strong compression. He reverses one end of the first, about four inches upon its body, and applies that reversed end to the hinder and upper part of the leg; the other head of the compress, passing over the stump, comes upon the knee. Afterwards the surgeon takes the second longitudinal compress, with both hands, by its two ends, and applies the middle of it upon the stump, conveying the heads all along the sides of the leg, to cross above the knee. Lastly, he applies the middle of the third longitudinal compress immediately upon the hinder part of the leg, on the edge of the stump; and then he proceeds to cross in the forepart, from whence the heads being conveyed upon the sides of the knee, cross one another above it, where they are stopped. That whole dressing is supported by the following bandage called the capelina with one head.

"*Of the Bandage called the capelina with one head.*—The roller that is to be used for the capelina with one head, in the amputation of the leg, must be three inches broad, and about six and thirty feet long. The surgeon begins that bandage with two circular turnings upon the edge of the stump, to compress the flesh and the fat, which swell as soon as they are exposed to

the air. Afterwards he proceeds by edgings to the knee, and when the globe is in the external part (I suppose the right leg has been cut off), he conveys it above, to pass laterally and internally upon the middle of the stump. In the next place he conveys the globe of the roller upon the knee, passing upon the external side of the stump; from thence he descends internally to pass a second time directly upon the stump, taking care that this last turning may cross the foregoing obliquely; he ascends upon the knee, about which he makes a circular to descend anteriorly and laterally, from above downwards, upon the stump, taking care that this third turning may still cross the first obliquely; so that those three turnings represent a stole, which is not only very neat, but also makes a considerable compression. Afterwards he ascends upon the knee to convey the globe under the ham, that he may descend all along the hinder part of the stump, and pass directly over it, by crossing with the first turning. Afterwards he conveys the list upon the knee, passing along the fore part of the stump, where he inserts it if he pleases to cross again twice upon the stump, or fill up the vacuities. Lastly, he ascends again upon the knee, from whence he descends obliquely to the lower circumference of the stump, where he makes one or two circular turnings, and then he ascends again obliquely to the upper part of the thigh, which is generally uncovered. The circumvolutions of the list reaching from the knee directly to the stump, are called the turnings of the capelina; these must be very tight, because they compress the vessels directly. The others, on the contrary, which we call circulars, being only used to encompass the first, need not be so tight by a great deal. Afterwards the surgeon lays down the patient, and places his stump upon a cushion somewhat raised; a servant stays by the patient and lays one of his hands upon the stump, and the other upon the knee, to compress the dressing directly upon the vessels. Some practitioners advise to put a compress, or noose, and a tourniquet, upon the internal part of the thigh, in order to use it, if the blood should come out, whilst the operator is sent for. The patient must keep to a strict and regular diet, and be blooded more or less, according

4

to his strength; for if he be of a sanguine or bilious constitution he ought to be blooded four or five times the first day, and twice, at least, the second day. By that prudent method, patients frequently save their lives, who would otherwise fall into convulsions, and a delirium, which would occasion their death."[1]

He further recommends in cases of secondary hemorrhage the use of the vitriol buttons, which should be applied to the bleeding vessels and pressed down firmly with compresses and lint.

I have cited nearly all that was said by this distinguished author on the subject of after-treatment. I have been prompted to this action by the fact that he lived during an important era in the history of amputations, and exerted a powerful influence on the minds of surgeons.

William Bromfield, surgeon to Her Majesty's Household, and to St. George's Hospital, who wrote a work entitled *Chirurgical Observations* during the latter part of the eighteenth century, supplies us with nearly the same instructions for the after-treatment. In cases of thigh amputations he recommends that the approximation and retention of the flaps be effected by the application of a roller bandage which is to be applied from the abdomen downwards. He thinks there is little gained by the early approximation of the soft parts. He employs dry lint over the bone: "Then a circular piece of old Holland, to lie within the skin on the muscles, which is of great service, as the rest of the dressings will come off easily when this is taken hold of; dry lint should be applied on this piece of linen, to fill up the cavities in the stump, and, in case the small vessels should weep, a little flour may be thrown on the bit of cloth or on the next layer of lint, which may also be assisted in its compression by applying a soft bolster of tow on the lint."[2] He further recommends the application on the lint of some digestive ointment to the edges of the flaps to prevent the dressing from sticking; externally to this he applies the same ointment on lint or tow.

[1] Loc. cit., p. 494 *et seq.*
[2] Chirurgical Observations and Cases, 1773, vol. i. p. 174.

The dressing is now to be retained in place by the stellate application of strips of adhesive plaster. He now gives a long description of the proper application of the cap, which is evidently intended to cover all the dressings previously applied, and which with this surgeon takes the place of the bladder that has been frequently mentioned by other authors. The cap is retained in its place by a few turns of the roller bandage. This dressing should be continued until suppuration is perfectly established, and then there should be a more perfect approximation and retention of the flaps. He accomplishes the latter wholly by the employment of adhesive plasters and bandages. He mentions the fact that he sprinkles the bandages with the spirit of wine in this stage of the treatment, and further adds: "Since I have made use of this method, the stump is generally healed in six or seven weeks, without any exfoliation of the bone;"[1] and he also conveys the idea that he now obtains a much more satisfactory stump.

The injurious effects arising from packing all sorts of wounds with linen, lint, and tow are referred to by Edward Alanson in the following language: "It was three weeks before the lint perfectly separated, it had formed so perfect an adhesion, and the granulations were so united with it, that many pieces of lint were left, which were picked out bit after bit at every dressing. This at the time occasioned pain, irritated the wound, and considerably protracted the cure; nay, even after the wound was healed, little pimples formed containing matter, from each of which we pulled out a small fibre of lint. This was constantly the case with the wounds after amputation during my apprenticeship; when the surface of every stump was covered with a load of dry lint immediately after the operation."[2]

The fact, that when the freshly cut flaps were laid immediately over the stump, inflammation and the formation of abscesses were almost sure to follow, had led to this packing with lint without any marked advantage, and consequently Sylvester

[1] Ibid. p. 179.

[2] Amputation and the After-treatment. Edin. 1782, p. 281.

O'Halloran, a surgeon at Limerick, was prompted in 1765 to make the experiment of deferring laying down the flap till the end of the first eight or twelve days after the operation, when it was conjectured that the risk of inflammation and abscesses would be diminished. This plan, with various modifications, has been and is still employed to a limited extent on both sides of the Atlantic under the cognomen, "Open Method of Wound Treatment." Prof. Billroth, of Vienna, was formerly a strong advocate of it, but seems now to incline to Prof. Lister's system of treatment. Prof. James R. Wood, of New York, has given much attention to this method of treatment, and furnished the profession with carefully formulated rules for its application.

It seems certain that Mr. C. Lowdham, of Exeter, England, was the first to suggest the possibility of obtaining union by first intention in cases of amputation; but Mr. Yonge published, in 1679, in his work entitled *Currus Triumphalis e Terebintho*, a letter, which is addressed to his friend Thomas Hobs, a surgeon in London, dated Plymouth, August 3, 1678, that begins thus: "Sir: I find by yours that you are surprised with the intimation I gave you, of a way of amputating large members, so as to be able to cure them per symphysin in three weeks; and without fouling or scaling the bone."[1] He then describes the operation, the laying down the flap over the face of the stump, and sewing it by four or five stitches. He also claims for this method that the cure is more speedy—not occupying one-fourth the usual time, neither suppuration nor exfoliation, diminished danger of hemorrhage, and lessened danger of reopening after the wound has been healed, and further, that it is better adapted to the pressure of an artificial limb.

These suggestions were soon forgotten, as was also the practice, if, indeed, it was ever put in practice, which Mr. Yonge's writings would seem to indicate; and it was not until Edward Alanson, after the lapse of one hundred years, renewed this method of treatment, and published a report of thirty-five consecutive amputations which he had treated successfully. This

[1] Samuel Cooper's Surgical Dictionary, ed. by Reese, N. Y. 1846, p. 53.

report, at the time, was condemned as false by those surgeons who had confined themselves to the *old methods of operative procedure and the lint-stuffing process* after amputations; but there was abundant proof even there furnished to satisfy all reasonable minds of the accuracy of these statements. The study of Alanson's report at this late date cannot fail to please every earnest student of surgery, and he will find not only much to admire, but something to learn.

The fact that Alanson recognized the same fundamental principles which underlie every form of antiseptic practice—a practice which has been reduced by Lister to a perfect system, and which has given results in surgery far more satisfactory than any of the old methods, entitles this surgeon of the eighteenth century to the *highest consideration and respect.* Dr. Stephen Smith has given a very careful summary of the after-treatment employed by this distinguished surgeon, which reads as follows: "The surface of the stump was well sponged with warm water. The skin and muscles were gently brought forward to cover the end of the bone, and were supported by a flannel roller passing about the body, and then down the limb smoothly and with moderate firmness until the extremity of the stump was reached. The skin and muscles were placed over the bone, so that only a bare line extended across the end of the stump, and the ligatures were left hanging out at the extremities of the incision in either side. If the skin did not easily cover the bone, strips of adhesive plaster were applied from below upwards. The many tailed bandage was employed. The stump was placed on a pillow and raised only about half a hand's breadth; this was a special feature. The dressings were changed no oftener than was necessary to secure perfect cleanliness."[1]

Prof. Syme gives to Alanson the credit of having banished the barbarous practice of wound-stuffing with lint which effectually prevented union by first intention. The work was accomplished, however, very slowly, and required many years of

[1] The Medical Record, N. Y. vol. xi. p. 756.

thought and study in England before it was even accepted in theory, and it was still later on the continent before it received recognition.

Baron Larrey, in his report of the first Saxon campaign, mentions that the Saxon surgeons divided the skin and muscles by means of a curved knife at one stroke, and the bone nearly on a level with the section of the soft parts, after which they drew the soft parts over the bone and introduced four or five stitches, and it was still further sealed up by the application of adhesive plaster. Neither did they apply ligatures to the vessels to control hemorrhage, but depended on the tight and close union of the edges of the wound to restrain the flow of blood. He, however, informs us that all their cases of *amputation died.*

The above remarks relate to the great battle at Lutzen, May 2d, 1813, in which the loss of life was very heavy on both sides, and therefore we may naturally conclude that the number of amputations was not small.

During the latter part of the eighteenth century surgeons had gradually abandoned the elaborate dressings in cases of amputation-wounds in which they had been accustomed to use so freely lint, ointments, balsams, and plasters for the purpose of employing humectives and greasy bodies. These changes were chiefly due to the teachings of Hunter and Alanson.

"Pibrac and Louis had, on the other hand, abandoned the use of sutures, and the local treatment of wounds was gradually almost reduced to agglutinative bands whenever primary unions were aimed at, and the use of cerates and cataplasms when it was no longer possible to avoid suppuration."[1] The use of the agglutinative bands was not entirely satisfactory, they did not hold the flaps well in contact, and consequently other measures were devised for this purpose.

August Vidal, in 1849, invented the *serre-fine*, which, instead of the suture, has been employed in some cases of amputation. This instrument with crossed arms acts like the smoker's forceps by the elasticity of the metal.

[1] St. Louis Med. and Surg. Journ., vol. xxxvi. p. 310.

Marcellin Duval, in 1853, invented an instrument which he called *Pinces à pression continue et graduée*. The application of these forceps is very easy, and they cause no pain. They are especially useful after amputations, as they hold in apposition the musculo-cutaneous flaps, thereby obtaining union of the whole extent of the cut surfaces, which it is possible to approximate without preventing the escape of the fluids from within. The pressure may be increased or diminished at will by turning a screw.

Metallic sutures were reintroduced into surgical practice about thirty years ago by J. Marion Sims, of New York. He owed his first success in the treatment of vesico-vaginal fistula to the use of the silver-wire suture.

Since 1849 the silver wire suture has been substituted for the silk or linen in many cases of amputation with very great advantage, although in our opinion many other metallic wires might be employed with equally good results.

In 1809, V. Kern, of Vienna, who condemned the use of charpie and ointments, substituted for them simple compresses soaked in lukewarm water. In 1827 Walther introduced this treatment at the University of Bonn.

In 1839 Langenbeck, of Berlin, praised the warm-water bath in the treatment of large wounds. During the Schleswig-Holstein war Langenbeck and Stromeyer employed it advantageously.

"Liston employed this method at the Royal Hospital, at Edinburgh, a long time, when in 1835 he imported it into the University Hospital at London, which had just been erected."

"In 1836 Macartney addressed to the Academy of Medicine a memoir in which he insisted on the advantage of repose, position, and cold water in the treatment of wounds of every nature.[1]" "Despite the authority of these two names, the water dressings have had some trouble in taking root in the hospitals of the united kingdom, and in the third edition of his *Operative Surgery*, published in 1840, Liston still raised his protest, in all

[1] Ibid. p. 311.

the power of the English language, against the routine errors, against the use of balsams, ointments, pledgets, compresses, and bandages, against daily washings performed with sponges of doubtful cleanliness, which he styled a *dirty, abominable* practice, *revolting to nature and common sense.* Liston remained faithful to his principles until the end of his life; they finished by gaining their cause, and in 1860 water dressings in the London hospitals were the rule."[1]

The mode of application was varied as well as the temperature of the water. Some surgeons preferred the water-bath; others employed irrigation, and many were satisfied by occasionally moistening the bandages covering the wound.

During the American war of secession water dressings were generally applied with the first bandaging after an amputation, and the same were continued until some change in the patient's stump or general condition seemed to indicate some other application. In cases where there was retention of an albuminoid fluid within the flaps, associated with symptoms of septic infection, it was customary to remove the stitches and apply an emollient poultice over the surface. It may be justly claimed that the American surgeons did not restrict themselves to any routine practice during this war, but endeavored to meet the indications in each case as they arose with the remedial agents within their reach.

The water treatment gradually spread over the world until it may now be safely asserted that it has been employed in the treatment of amputation wounds for a longer or shorter period by all the civilized nations of the earth; nevertheless, this mode of treatment, so very economical and so easy of application, appears to have had its day. The recent investigations into surgical pathology have satisfied our ablest surgeons that septic infection is the cause of nearly all the accidental wound complications, and that no application of water offers sufficient protection against it. "It was under this influence that was born the greater part of these methods that we are about to review.

[1] Ibid. p. 312.

Although they are somewhat numerous, they group themselves without effort about two principal indications. The one class has for its object the neutralizing of some active toxic principles; the other the protection of the wound from contact with them. We designate the first under the general name of antiseptic dressing; the other under the name of treatment by occlusion."[1]

In 1855 Demarquay employed glycerine in the treatment of hospital gangrene during an epidemic which occurred at the Hospital St. Louis, and the success surpassed his expectations. Four years later he published a long memoir in which he lavished on this drug the highest praise, and presented it as an almost certain prophylactic in erysipelas, purulent infections, and hospital gangrene; but this opinion has long since proved erroneous, and glycerine has taken a modest rank in therapeutics.

The disinfecting powder of Corne and Demeaux was the next antiseptic which made its appearance, and was brought before the Academy of Sciences by Velpeau. It was shown that in all cases where the mixture had been employed disagreeable odors had disappeared. "The action of this substance seemed to arrest the progress of decomposition. It kept away the insects, and prevented the production of organisms."[2] The communications made to the learned societies in regard to this powder by Velpeau and others awakened a deep interest in the minds of surgeons and chemists in reference to disinfectants. They were able to show that this study was not new, and that already many agents had been employed for this purpose. However, the reputation of this powder soon reached its limit. The trials made in the hospitals had established the fact that it neutralizes the odor of pus only by absorbing it, and that it absorbs only a very small quantity; that the liquid remaining under the crust formed by this mixture retains all its disagreeable odor; that the application ought to be renewed very frequently, and that the gray powder deprives the treatment of

[1] Ibid. p. 314. [2] Ibid. p. 445.

every character of cleanliness. It was not slow, therefore, to be abandoned in the treatment of wounds.

Finally, coal tar reappeared in a new form, and relieved of the inconvenience which had been a reproach to it in an excellent preparation known under the name of "*coal-tar saponine*," with which Le Beuf, a pharmacist of Bayonne, had enriched therapeutics.

Bobœuf proposed in 1860 as a substitute for coal tar the alkaline carbolates, solutions of which are always identical, while the composition of the former is essentially variable. The employment of the carbolates naturally led to the use of carbolic acid. In 1865 Declat addressed to the Academy of Sciences of Paris a note in which he presented it as a true panacea.

Since that time the use of this therapeutic agent in the treatment of wounds has extended to all the civilized nations of the earth. Lister has adopted it in an exclusive manner. His antiseptic treatment has acquired great celebrity, has been and still is employed in most of the continental and American hospitals. This treatment is based essentially on the parasiticidal property of the carbolic acid, which he employs in the following manner: he operates in an atmosphere charged with the spray of this acid; the instruments, the hands of the surgeon and assistants, the ligatures, the dressing, everything which touches the patient is soaked in it, and not a septic germ can escape it. The first publication in regard to the antiseptic treatment was made by its author in the *Lancet*, March 16th and 23d, 1867.

Prof. Thiersch, in 1874, substituted salicylic acid for the carbolic as a surgical antiseptic, but it has made very little progress.

In the summer of 1877 Dr. Hans Ranke, after a consultation with, and by the advice of Dr. Richard Volkmann, began to employ Thymol in the surgical clinic at Halle, in the antiseptic treatment of wounds. This remedial agent proved to be satisfactory in the hands of the original experimenters, but its employment has not yet been popularized. Many other antiseptic

agents have been and still are occasionally employed in the treatment of amputation wounds; but I shall mention those most frequently used, which are the following: Ice, permanganate of potash, alcohol, whiskey, boracic acid, chloral hydrat, sulphurous acid, the sulphites and hyposulphites of lime, magnesia and soda, lotions of lead, terebinthine, and common salt.

We now proceed to a consideration of the treatment of wounds by occlusion. We designate by this expression every method of treatment which protects the wound from contact with the air. The principles on which rests the occlusive method of wound-dressing is not a recent discovery. At the commencement of the seventeenth century César Magatus praised infrequent dressings, which accomplished the conditions of occlusion. The ideas expressed by this author have not been lost; we find them repeated and strongly emphasized in a work entitled *Clinical Lectures on the Treatment of Wounds* by Sampson Gamgee, F.R.S.E., which was published in London in 1878. However, Gamgee's treatment includes the use of drainage tubes, a splint which is employed to render the limb immovable, constant, gentle, and uniform pressure over the stump, which is also surrounded with cotton-wool. He strongly objects to washing or sponging the fleshy cut surfaces where union by first intention is desired, and does not permit the cotton-wool to be moistened, but employs it perfectly dry. He further urges that no dressing shall be changed until the temperature chart shows that such a proceeding is necessary, and consequently the changes are infrequent.

Partial occlusion by agglutinative plasters has long been employed in the treatment of ulcers. In England it bears the name of Boynton's treatment, but there is much doubt in regard to its originator,

In the month of October, 1844, Langier addressed to the Academy of Sciences a note on the successful employment of mucilage of acacia and goldbeater's skin in cases of amputation of the breast, and proposed to use it in thigh amputations. At a meeting of the same body on November 11th, 1844, Jules Guérin claimed priority, and referred to a trial which he had

made with goldbeater's skin two years previously in the temporary service of Maisonneuve at the Hôtel Dieu.

These defective occlusive measures having proved unsatisfactory, in 1866 Jules Guérin proposed to the Academy of Medicine and the Academy of Sciences pneumatic occlusion. The vacuum was produced over the wound or stump by the aid of an air-pump with rubber cushions destined to mould themselves on the parts and communicating with the reservoir by rubber tubes, finally with an intervening envelope of a very fine elastic tissue and permeable enough to apply itself immediately on the wound inclosed in the cavities of the cushions.

On the same day on which Jules Guérin made the preceding communication to the institute, Maisonneuve exhibited to it, under the name of continued expiration, a system which differed but slightly from that called by Guérin pneumatic occlusion, but the latter claimed priority, and the former yielded it. This apparatus for the treatment of wounds by pneumatic occlusion, when slightly modified, enables the surgeon to surround the wound with an artificial atmosphere.

The experiments made by Demarquay and Leconte, in 1862, have established the fact that certain wounds of an unhealthy character are cured with remarkable rapidity under the sedative and cicatrizing influence of carbonic-acid baths. This artificial atmosphere has been further employed in the same class of cases, and has fully sustained the reputation given it by the original experimenters.

In regard to the other gases which have been employed in the treatment of wounds, there is less to be said in their praise.

Lannelougue proposed a much more simple way of forming a vacuum over the surface of amputation-wounds. His process consisted in placing the stump in a pocket formed of two sheets of rubber in apposition like those of a French night-cap. When it is enveloped in this sort of artificial serous membrane, air is blown into the cavity between the layers of rubber, the internal wall applies itself accurately to all the irregularities of the traumatic surfaces, whilst the rest expands about the neighboring parts of the limb. The method proposed by Prof. Bouis-

son, in 1857, which consists in drying the surface of a wound either by a natural or artificial current of air is only another plan of treatment by occlusion. The drying is followed by the formation on the surface of the wound of a thin pellicle, which effectually excludes all air until it is cracked by the motion of the parts or some other power. This process has been found to work very well in small superficial wounds.

The raw-cotton dressing, another means of treatment of wounds by modified occlusion, was introduced in the Hospital St. Louis in 1874, by Dr. Alphonse Guérin, of Paris. This treatment, which is based on the teachings of Pasteur, that putrefactive fermentation is due to the presence and growth of vegetable organisms, which float in the air and thus gain admittance to fresh wounds; and as it has been shown that these minute bodies become entangled in the meshes of cotton-wool, it therefore occurred to M. Guérin that this knowledge might be applied advantageously to the treatment of amputation-wounds. The application of this method was followed by an improvement in the condition of this class of patients, but it has since been shown that it is not a certain prophylactic against purulent infection.

CHAPTER II.

PRELIMINARY CONSIDERATION OF THE CONDITIONS AFFECTING THE RESULTS OF AMPUTATIONS OF THE EXTREMITIES. AGE, HABITS, FUNCTIONAL DERANGEMENTS, ORGANIC DISEASES, AND HYGIENIC SURROUNDINGS.

It is the duty of all surgeons before performing an operation to examine carefully into every condition which can affect the result. The performance of this duty requires not only a close investigation of the moral, mental, and physical peculiarities of the person on whom it is proposed to operate, but also a thorough knowledge of his present and past habits, hereditary tendencies, and hygienic surroundings. Sir James Paget remarks: "If I were to count the number of preventable calamities in surgery that I have known, I should find the majority of them due to the oversight of personal defects in the patients operated on; defects in the habits, the constitution, or the previous diseases, which ought to have been ascertained before the risk of the operation was incurred."[1] The importance of proper hygienic surroundings may be readily inferred by a casual examination of the surgical literature of the last fifteen years. During this period the most skilful physicians on every part of the civilized globe have been diligently searching for death and danger in the air we breathe, as well as in the food and fluids which we employ to nourish our bodies. These conditions which influence the results of amputations may be grouped in two classes, which we will designate as corporal and hygienic. The term corporal, as here employed, includes all those conditions which belong essentially to the body, and the word hygienic

[1] Clinical Lectures and Essays, ed. by March, New York, 1875, p. 68.

relates to the influences which are external to the same. Let us now enter more specifically into the details of these conditions which have been thus far outlined. The remark is frequently made, that the age of the patient is favorable for the operation, although this vague sentence conveys little meaning to any one except an experienced surgeon.

Sir James Paget says: "I believe that after two or three years old, the increase of age is attended with a proportionate increase of liability to death and other ill consequences of operation."[1] This opinion is said to be based on hospital reports and similar tables, and although its accuracy may be questioned, for the obvious reason that very few children of the age mentioned by this distinguished author require operations. It therefore follows that the statistics bearing on this subject are very meagre and unsatisfactory. In connection with this subject it may be further remarked that there are other elements which necessarily complicate this question. Children of this tender age are exempt from the dangers attendant on labor and machinery, and consequently the injuries which they do receive are less frequent and also less dangerous to life and limb. Every surgeon who has had much to do with injuries arising from the employment of machinery in workshops and factories, will readily admit that although there are many cases in which the full extent of the lesion can be easily determined at the first examination; that there are also a considerable number in which the danger at an early period cannot be even approximated, since the extent of the injury is not immediately apparent to the most acute observer. This class of injuries forms an important element in all cases of primary amputations, and should be considered in connection with the statistics of the same. The chief danger in cases of operation on young and robust children does not arise from septic infection as in adults, but from shock and pain. They bear pain badly, and it increases greatly the danger. The many diseased conditions arising from dentition in these young subjects may prove a serious complication in case of surgical

[1] Ibid. p. 5.

operation. The bad hygienic surroundings of the tenement-house population in our large American cities and towns in which scarlatina, diphtheria, measles, whooping-cough, and other contagious diseases prevail almost constantly among the children of the poor, must therefore be regarded as a standing menace. The high ratio of mortality among children under five years of age compared with that among those which are older, and the frequency with which these diseased conditions become either directly or indirectly complications of surgical operations must certainly militate against a high degree of success in the treatment of this class of patients.

The Superintendent of Census, Francis A. Walker, when speaking of the mortality of this class, says: "As a matter of fact we find that 41.4 per cent. of the whole body of deaths occur under five years of age, and 46.7 per cent, under ten years of age, while of the total of living inhabitants 14.3 per cent. were found to be under five years of age, and only 26.8 per cent. under ten years of age."[1]

Dr. Thomas B. Curtis, of Boston, when writing on the subject of vital statistics, calls attention to the fact that, "according to Dr. Wm. Farr, the mortality of districts increases with the density of their populations; not, however, in the direct proportion of their densities, but as the sixth root of their densities. The uniformity and accuracy of this law are very remarkable. Having calculated the death-rates of seven groups of districts from the densities (population to a square mile) of those groups, Dr. Farr found the district death-rates to approximate very closely the observed actual death-rates of the groups of districts. The calculated death-rates being 18.90, 19.16, 20:87, 25.02, 28.08, 37.70, 38.74; the corresponding observed rates were 16.75, 19.16, 21.88, 24.90, 28.08, 32.49, 38.62. We have seen to what extent the mortality at all ages is influenced by density of population.

The ill effects produced by undue concentration of inhabitants are much greater in the early years of life than in subsequent ages. Infants and young children are far more sensitive than

[1] Volume on Vital Statistics, Ninth United States Census, 1870.

adults to this insanitary agency, as the following figures, relating to seven groups of English districts, show:—

Persons to a square mile,	166	186	379	1718	4499	123.57	65,823
Death-rate at all ages,	16.94	19.18	21.90	24.81	28.02	32.92	38.67
Death-rate under five,	37.80	47.53	63.06	82.10	95.04	111.90	139.52

"The figures in the last column of this table relate to the Liverpool district. . . . Excessive density of population is a complex condition, implying a combination of many separate and distinguishable morbific agencies. The part played by each of these is capable of more or less accurate analysis and statement by means of vital statistics relating to the hygienic, social, and financial conditions prevailing in different communities. The methods and results of such investigations cannot here be set forth."[1]

The question may now be asked with propriety, what age furnishes the greatest immunity from death and other ill-consequences of surgical operations? It is believed that the study of the average rates of mortality from all causes will greatly aid in the answer of this important question, and for this purpose the following table is cited, "which gives the average annual rates of mortality in England and Wales, according to the returns of thirty-four years (1838–1871), for males and females, at all ages, and at twelve periods of life:—

AGES.	MALES.	FEMALES.	AGES.	MALES.	FEMALES.
All ages	23.3	21.5	All ages	23.3	21.5
0– 5	72.6	62.7	45–55	18.5	15.6
5–10	8.7	8.5	55–65	32.0	28.0
10–15	4.9	5.0	65–75	67.1	58.9
15–25	7.8	8.0	75–85	147.1	134.3
25–35	9.9	10.1	85–95	305.5	279.5
35–45	13.0	12.3	95 and upwards	441.1	430.4 "[2]

[1] Ziemssen's Cyclopedia of the Pract. Med. vol. xix. Supplementary vol. on Hygiene and Public Health, p. 322.
[2] Ibid. p. 321.

This table shows that the lowest annual mortality occurs between the ages of ten and fifteen, and that the number of deaths during this period among females is slightly in excess of those among males. The fourth period is entitled to the second place on account of the low ratio of mortality; and still we find the number of deaths among females between the ages of fifteen and twenty-five, in excess of those among males, whilst the second period takes the third place, and the ratio of mortality between the sexes is reversed. A more extended analysis of this table is not required for our purpose, although each period with its figures supplies an important topic for study. Let us therefore return to our original question, and determine as far as possible the period of life most favorable to surgical operations; and whether the general ratio of mortality from all causes, at different periods of life, does not in a measure correspond with that occurring in surgical cases. Sir James Paget says: "We have a large number of printing-offices in the neighborhood of the hospital, and every office employs many boys from twelve to sixteen years old, and hardly a week passes but we have one or more of these boys brought in crushed by the printing machines. Fingers, hands, and arms are thus mutilated; and I know no class of patients that recover more remarkably. Not only do they not die, but their wounds heal steadily and quickly; they escape erysipelas and spreading suppurations, and secondary hemorrhages; and often, when, to save any piece of a hand, we leave bits of skin that seem as if they could not live, they yet do live and grow good scars. I know no class of persons who are better subjects for operations than these boys. As Mr. Callender has pointed out, our success with them helps to bring us the credit of a very low rate of mortality in amputations of the upper extremity."[1] We think it will be generally admitted by experienced surgeons, that this class of patients make excellent recoveries from severe injuries; but my experience compels me to doubt whether they are really better subjects for surgical treatment than those who are some-

[1] Clinical Lectures and Essays, ed. by March, p. 4. New York, 1875.

what younger. I am now able to recall to mind many remarkable recoveries from severe injuries which have occurred in children between the ages of five and twelve. Some of these cases were in my own practice, and others in the service of my colleagues. These diverse injuries involved various parts of the body, and were produced in divers ways. Some belonged to that class commonly designated as railroad injuries, in which surgeons have to deal with extensive contuso-lacerated wounds of the soft parts, as well as with comminution of bone; and others were brought in from workshops and factories. The different surgical operations performed in these cases and in fact the entire treatment were attended with much more satisfactory results than those which we attained in our practice among adults. Among these patients the number of males was in excess of the number of females; but the results were equally favorable in the latter class. I am therefore inclined to the followiug opinion: 1. That there is no more favorable period for the performance of surgical operations than that between the ages of five and fifteen. 2. That during this period ordinarily the question of sex has much less importance than at a later date. 3. That the average annual rates of mortality for various ages and different periods may be received as a relative guide in cases of severe injuries and surgical operations, as far as age and sex have a bearing on the question of life and death. Let us now briefly consider some of the agencies which have undoubtedly a bearing on the mortality arising from disease and injury at the different periods of life. It has already been shown by statistics that the death-rate among children under five years of age, is more than seven times as high as it is among those between five and ten; and further, that the ratio of mortality during the first period is more than thirteen times as high as it is during the third.

We have previously mentioned some of the morbific influences from which this high ratio of mortality arises during the first period, but have not discussed its bearings on the other periods of life. The doctrine of natural selection, or what has been designated by Herbert Spencer as the survival of the fittest, is

as applicable to the human race as to the lower order of organic beings, for man's existence is a continual struggle to maintain life. The same law which declares that only a small portion of the numerous offspring born of the lower class of organic beings can survive is also applicable to man, although the application may differ in degree. The devastating effect of disease removes during the first period of human life the majority of the feeble children and leaves the stronger. The same process of selection is in force during every period of human existence, but the effect produced by this power will be unquestionably greatly modified by the existing hygienic surroundings and corporal condition of each individual. Every period of human life is attended with new conditions, and these frequently bring with them new dangers, some of which are peculiar to the age or sex of the party, while others take their origin from a diversity of causes. Children of both sexes, between the ages of five and fifteen, are generally accustomed to take much exercise in the open air, are essentially free from mental anxiety and pernicious habits, eat well and sleep soundly. The process of natural selection having previously performed the greater portion of its work for childhood leaves for the future struggle a healthy progeny. It is under these conditions and these ages that we find our patients after surgical operations making the most rapid and satisfactory recoveries. It will be observed that the fourth period of life, according to our table, or between the ages of fifteen and twenty-five, is marked by a comparatively low ratio of mortality from all causes. Does this ratio of mortality from all causes here represent comparatively the success that the operator may justly anticipate in surgical cases? We have no figures on which to base our reply, but it is proper here to call attention to the fact that during this period there are sources of complication not generally found in the preceding periods. During the period now under consideration mental and sexual complications must receive attention. The mental condition will generally correspond with the severity of the injury and the degree of deformity which is likely to arise from it; however, the surgeon is often compelled to recognize the fact that all

persons are not possessed of the same mental and physical qualities; that some are innate cowards, while others are by nature heroes. A patient belonging to the former class receives an injury, soon afterwards becomes despondent, will neither eat, drink, sleep, nor smile. He no longer clings with tenacity to life, and the death which he covets frequently comes to his relief. Here we have described a form of despondency, so severe that it in fact amounts to a foreboding of death; although the same complication is frequently seen in a much milder form. There is another side to this picture, another class of patients who instead of yielding to a feeling of despondency struggle manfully for life; the prospect before them is never so dark as to blind their hope; they are able at all times to discern some object for which they wish to live. The surgeon in the early stages of illness finds the latter class in a mental condition diametrically the opposite of the former, and after the lapse of a few days it will be observed that the physical divergence has become equally marked; both patients will be found to be progressing, one towards recovery and the other towards the grave. These mental peculiarities exist in every race and are found in both sexes. They may be regarded as belonging to the unsolved problems of surgery. The functional disturbances of the sexual organs which effect persons between the ages of fifteen and twenty-five are seldom of sufficient importance to require much consideration except in determining the time for the performance of a surgical operation in the case of a female. The performance of any important surgical operation should be carefully avoided if possible, immediately before or during menstruation. The existence of pregnancy should also be regarded as a similar barrier. The necessity of adhering to these rules as long as the condition to which they apply exist, and the importance of the same are thought to be so obvious as to require no further explanation. Different organic diseases of either the male or female sexual organs may become a complication of a surgical case, and therefore their relation and importance should not be overlooked in this connection, but suffice it, that the more important diseases of this class will be referred to further

on in this chapter. It will be observed by a reference to the last table that the mortality between the ages of twenty-five and forty-five from all causes is comparatively low, although it is somewhat higher during the last ten years of this period; that during the next decade it ascends rather rapidly and the same continues to the end of life in a progressive series.

Sir James Paget has said that "the chief interest in connection with age is in the cases of old persons, for among them are patients in whom nearly every risk of operations rises to its maximum. Nor will this seem strange if you consider how many disadvantages for the bearing of injuries old age brings with it. The longer a man lives after middle age, the more likely is he to have some organic disease, the more certain is he to have many degeneracies. Hence, to name one source of trouble, the tardy circulation, and the various congestions due to mere sinking of the blood, not in the lungs alone, but in the liver and intestines and all other dependent parts—facts to be much considered in regulating the postures of old people after operations. But the extreme of unfitness for injuries you may see in some of the poor old creatures on whom we are forced, by glimmers of hope, to operate for hernia. They are so near death that, temper it as we may, the least shock kills them. But among the old there are even greater differences than among the young in the ability to recover from operations; and age, if reckoned by years, is not the only thing in them that we must estimate. Years indeed, taken alone, are a very fallacious mode of reckoning age; it is not the time, but the quantity of a man's past life that we have to reckon; and for this estimate, with a practised eye, looks are less deceptive than a tale of years. Even among those old patients to whom you cannot impute disease you may easily, by their appearances, make out some groups very different in their bearing of injuries. They that are fat and bloated, pale with soft textures, flabby, torpid, wheezy, incapable of exercise, looking older than their years, are very bad. They that are fat, florid, and plethoric, firm-skinned, and with good muscular power, clear-headed, and willing to work like younger men, are not indeed good subjects

for operation, yet they are scarcely bad. The old people that are thin and dry and tough, clear-voiced, and bright eyed, with good stomachs and strong wills, muscular and active, are not bad; they bear all but the largest operations very well. But very bad are they who, looking somewhat like these, are feeble and soft-skinned, with little pulses, bad appetites, and weak digestive power; so that they cannot, in an emergency, be well nourished."[1] The chief danger with which we have to contend in surgical cases among those patients who are really old, or prematurely old on account of injurious habits, generally arise from functional disturbance due to diminished vital power, or organic disease. The lowered vital power is manifested by a diminished power of endurance; and consequently we find that the old are much more liable to die from shock, exhaustion, loss of blood, and other debilitating influences. Their wounds heal slowly, and hence there is increased liability to secondary hemorrhage and other accidental wound complications.

Sir James Paget says: "Their convalescence is often prolonged; and you may expect to meet sometimes with great disappointment in having your old patients die with some slight casual disease, as if exhausted by the long expense of vital power in healing large wounds. They get all but well; and then, after seeming for some time stationary, they fade, and waste, and die. They fulfil what I have often told you of the diseases of the aged; that there are some to whom convalescence is more dangerous than disease. . . . In saying these things about the old, I have had in view only those patients who may call themselves 'well for their age,' and in whom you may find no signs of disease. Infirmities they have—degenerations and decays accumulated and perhaps premature—yet not diseases. Now let me add, that of all the conditions of disease or imperfect health of which I have next to speak as influencing the results of operations, there is no graver complication than old age, unless indeed it be habitual intemperance."[2]

It is a well-known fact that the performance of surgical

[1] Ibid. p. 6. [2] Ibid. p. 7.

operations on persons addicted to the intemperate use of alcoholic beverages is attended with a high degree of danger to the patient. This danger may arise from functional derangement, organic disease, or the combined influences of both conditions. The danger does not alone belong to the chronic drunkard whose entire body is continuously saturated with alcohol, and who by the long-continued use of this beverage has so greatly weakened the assimilative powers of the system, that only a small quantity of food can be assimilated; but the surgeon must also be cautious in his operations on the fashionable tippler and the patient who occasionally goes on a little spree. Each of these classes has its own particular danger, which is stated in the following words of Sir James Paget: "I think you will find that a habit of slight intemperance is much worse than occasional great excesses; that regular soaking is worse than irregular carousing; probably because of the steady impairment of the blood and of all the textures to which the soaking leads. Of course, you will keep your hands off notorious drunkards, unless you are driven by the stress of a strangulated hernia or a stopped windpipe, or something leaving you as little choice as these do. But you must be on your guard to detect a good deal of drunkenness of the soaking kind which is not notorious and not confessed. Be rather afraid of operating on those of whatever class who think they need stimulants before they work; who cannot dine till after wine or bitters; who always have sherry on the sideboard; or are always sipping brandy and water; or are rather proud that because they can eat so little they must often take some wine. Many people who pass for highly respectable, and who mean no harm, are thus daily damaging their healths, and making themselves unfit to bear any of the storms of life. Especially they are doing so, who increase their stimulants while they diminish their food. This is a fatal error, much worse than that of both eating and drinking in excess."[1]

Mr. Neison has shown that the maximum rate of mortality

[1] Ibid. p. 14.

in intemperate lives occurs between the ages of forty-one and fifty, and that the average duration of life after the commencement of intemperate habits is, among beer-drinkers, twenty-one and seven-tenths years; spirit drinkers, sixteen and seven-tenths years; and among those addicted to the indiscriminate use of both distilled and fermented liquors, sixteen and one-tenth years. The above figures seem to show that the danger to life attending the intemperate employment of distilled liquors as a beverage is greater than that which follows the use of fermented, and that both combined are worse than either taken separately. I think it is probable that when distilled liquors have been employed in such quantities as to completely saturate the whole body during comparatively long periods, this degree of intemperance may be more frequently followed by organic disease and death than any condition which may arise from the use of fermented beverages; but functional disturbances and various degenerations occur more frequently among the so-called moderate beer-drinkers than among those who are designated by the same adjective, but employ whiskey to quench their thirst. The moderate, as well as the intemperate beer-drinker, is especially liable to suffer from septic infection after surgical operation. Slight injuries, in this class generally give rise to cellulitis, which then spreads with great rapidity, and this condition is quickly followed by purulent infiltration, while the severe injuries are often complicated by septicæmia, pyæmia, or osteomyelitis. The surgeon who is compelled to operate on this class of patients ought not to forget that they are particularly prone to die from slight causes, and consequently he should take every possible care to prevent the absorption of septic poison. The majority of beer-drinkers in this country are Germans by birth, and many of them are over-fat. Sir James Paget says: "The over-fat are certainly a bad class, especially when their fatness is not hereditary, but may be referred in any degree to their over-eating, soaking, indolence, and defective excretions. The worst of this class are such as have soft, loose, flabby, and yellow fat, and I think you may know them by their bellies being pendulous and more prominent than even their

thick subcutaneous fat accounts for, for this shape tells of thick omental fat, and, I suppose, of defective portal circulation."[1]

It has been stated already that intemperance is a common cause of functional derangements and organic disease. The organs most frequently diseased are the stomach, liver, and kidneys, and diseases of these organs are fraught with the highest degree of danger in our surgical cases. The various forms of dyspepsia to which the intemperate are so subject often interfere greatly with the process of nutrition. Dyspepsia may either delay or otherwise embarrass recovery, and occasionally it endangers the life of the patient. It is not our intention here to convey the idea that the intemperate are the only class who suffer with dyspepsia, or that it exists only among drunkards as a troublesome surgical complication. The fact is that this complaint may become a serious complication in any of the cases in which large feeding is necessary, especially if the disease is attended with frequent vomiting. Having briefly referred to some of the complications arising from the stomach in cases of surgical operations, we will now enter on a similar consideration of those which are associated with the liver.

Sir James Paget remarks that "among diseases of the digestive organs which occur in sufficient frequency to affect the risks of dying after operations, I suspect that none are of greater importance than those of the liver."[2] He cautions the surgeon against operating on patients who habitually suffer from functional affections of this organ. The morbid conditions are generally supposed by physicians to arise from different causes, although very little is known of their pathology or distinctive characteristics; however, it will suffice our purpose that we mention the more important symptoms of the group, which should warn us against incurring too great a risk, or giving too favorable a prognosis in our surgical cases. Patients suffering from these affections frequently complain of a sense of weight in the right hypochondrium, impaired appetite and digestion, occasional nausea and vomiting, constipation, or, more rarely, diarrhœa, a bitter taste, headache, sallow, dusky complexion,

[1] Ibid. p. 14. [2] Ibid. p. 28.

dry skin, sallow, bloodshot conjunctivæ, and sometimes there is found besides these a dilatation of the small bloodvessels of the face. The various functional derangements of this organ, whether they pertain to the circulation of the blood, the secretion or excretion of bile, or its glycogenic functions, are each important to the surgeon, because of the influence which they exert in surgical cases. These conditions lower the vital powers, and consequently render a patient less able to endure any strain on his physical system. The successful management of any condition is frequently greatly aided by a full comprehension of its nature and origin, and consequently a knowledge of the fact that these functional disturbances are often caused by intemperance, gormandizing, sedentary habits, or a severe mental strain, will not merely suggest the propriety of a preparatory course of treatment prior to the performance of any important surgical operation, but the remedial measures employed should be such as are required by the peculiarities of the case. Allusions have already been made to the functional disturbances of the liver as a surgical complication, but it should not be forgotten that organic diseases are, however, of much more serious importance. The different forms of degeneration of this organ must all be regarded as more or less important surgical complications. Sir James Paget has remarked that there are certain forms of this disease "which you must look to, especially the enlargement of the liver, whether amyloid or fatty, which is not rarely coincident with chronic diseases of the bones in children and young persons. This is undoubtedly a frequent cause of death after resection and amputation, from which, in healthy children, the mortality is so small. In some it merely seems to hinder recovery and they die slowly exhausted; in some I believe you will find it the chief reason for such defective healing as leads to secondary hemorrhage. The fear of consequences such as these may give you the rule never to operate for chronic diseases of bones or joints without a specially careful examination of the liver, for although its diseases may be comparatively most frequent in young patients, they may be found at any age."[1]

[1] Ibid. p. 29.

Dr. West, in referring to this subject, remarks: "Diseases of the liver and kidneys must be looked for, and, if detected, be carefully considered as to their bearings on operations in children, but the rules used for adults may be somewhat modified for children. The affections of these organs are generally either fatty or amyloid degeneration depending on prolonged suppuration. In the advanced stage of either form operations are highly dangerous. But, on the other hand, these conditions are not incurable, and instances might be given in which enlargement of the liver and albuminuria have completely, though very slowly, disappeared when suppuration ensued, and operations performed while these affections were in their early stage have not been adversely influenced by them. I believe an operation is not improper, but under favorable local conditions rather called for while these diseases are incipient, for if it can limit the amount of suppuration it may be the means of arresting their further advance."[1]

Dr. West mentions a form of enlargement of the liver which is always associated with a syphilitic or scrofulous cachexia in children, "generally slow in its development, and comparatively unimportant in its results as long as the kidney is unaffected by it; but then becoming dangerous to life and being amenable to no kind of treatment."[2] Having referred previously to a case of this disease in which there was very little impairment of the general health during a period of several years which it was uuder his observation, he adds: "Cases of similar kind have since come under my notice in children of very different ages, and accompanied with various degrees of disorder of the gene-health. In every instance there were obvious indications of a scrofulous habit, and in some nutrition was but ill-performed. The disease, however, which consists not in simple hypertrophy of the organ but in the interstitial deposit of an albuminous matter, does not usually produce any serious results so long as it is limited to the liver, or to that organ and the spleen. But in some instances a similar deposit takes place in the substance

[1] Diseases of Childhood, 4th ed. p 34. [2] Ibid. p. 539.

of the kidneys, blocking up the tubules, and interfering with the proper discharge of their functions, albumen then appears in urine which is secreted in only small quantities, anasarca and ascites come on, and death takes place eventually as the result of the renal disease, not of the mere affection of the liver."[1]

The diseases of the liver, which we have already mentioned, are entitled to a careful consideration, because of the frequency with which they are found to exist as surgical complications; and besides these there are other affections of this organ which should not be disregarded in connection with operative surgery. The frequent occurrence of cirrhosis among hard drinkers should serve here to direct the attention of the surgeon especially to the liver prior to the performance of an operation, and if this disease is found to exist in a somewhat advanced stage, it ought then to be regarded in about the same light as cancer or yellow atrophy of this organ, the existence of which effectually bars all surgical procedure, except it be under the most urgent circumstances, and even here severe operations may be expected to terminate fatally, or at most to prolong merely a diseased life a few days. Many other organic affections are occasionally met with in the liver which may become surgical complications, such as abscess, cystic disease, and gummy tumors, but they do not require any special attention in this connection. Our attention has been called by Dr. West to the fact that certain forms of disease of the liver only become dangerous to life when the kidneys become diseased; and Sir James Paget expresses the opinion that certain diseases of these organs increase the risk of operations, more than do the equally chronic diseases of any other internal organ. The diseased conditions of the kidneys so much dreaded by surgeons, as generally indicated by a careful examination of the urine, and even a knowledge of the fact that pus or albumen has been continuously or intermittingly present in this fluid during a specified period, is of the highest importance. However, no examination of the urine should terminate with the discovery of albumen, but should be carried

[1] Ibid. p 539.

forward by the aid of the microscope for the purpose of detecting any casts which may be present, and the character of the same. These casts have a diagnostic and prognostic value. They aid greatly, when carefully studied, in determining the true character of the disease and its stages. A failure to discover them, or even their absence in cases of chronic and continuous albuminuria, should not, however, be construed as a positive demonstration of the non-existence of organic disease of the kidneys, but in these rare cases the ophthalmoscope may supply additional information. Sir James Paget has called attention to the greatly increased danger arising from septic infection in cases of operations on patients suffering with chronic albuminuria, and here he adds: "The risks of erysipelas and of pyæmia seem to reach their climax. . . . All the dangers of which you are taught in medical lectures as to the tendency of albuminuria to generate pericarditis, pleurisy, and other internal inflammations, are proved emphatically when the patient's general health is disturbed by the consequences of injury, whether accidental or by design."[1]

The discovery of pus in the urine, if it be shown to come from the kidneys, and to arise from the disorganizing effects of pyelitis, should be regarded as an indication of a grave pathological condition; and should a further examination of the patient reveal the fact that both kidneys are diseased, it may then be safely asserted that no form of degeneration of these organs offers a more unfavorable complication in surgical operations. The patient's strength will be found to be already greatly exhausted, the most important excretory organs in the body so far disabled as to be no longer capable of performing properly their functions, the whole body vitiated by the retention of the effete materials, and all the other organs more or less embarrassed or deranged from the same cause. In this condition the heart, stomach, or any other organ, may at any time refuse to perform its work, and inasmuch as only a slight blow is required to extinguish the flickering spark of like, death will quickly follow.

[1] Loc. cit. p. 39.

It will readily be perceived that these comments are not merely applicable to the various forms of degeneration affecting the renal organs, but that any form of organic disease may here give rise to similar disturbances and be followed by the same results.

Let it be remembered that it is not our intention to enter here on a systematic treatise of disease, but to point out some of the most common causes of disappointment and failure attending the performance of surgical operations which are dependent on the existence of morbid conditions of the various organs. Having already called attention to some of these conditions, as they are found in the kidneys, it now remains for us to urge all surgeons to make a careful examination of the urine prior to the performance of any important surgical operation. The value of this examination will chiefly depend on the thoroughness with which it is made. It should be so thorough as to determine positively the presence or absence of albumen, sugar or pus; and it must be even admitted that an examination of this kind may occasionally fail to detect certain forms of organic disease of the renal organs, although generally the information thus obtained is very valuable. The medical profession is greatly indebted to Sir William Gull and Dr. Sutton for the pathological knowledge which we now possess of arterio-capillary fibrosis, a disease which generally occurs in persons who have passed the middle period of life and among those who are predisposed to chronic Bright's disease, such as the subjects of gouty diathesis, dyspeptics, and alcoholists. The so-called moderate drinker is supposed to suffer more frequently from it than the confirmed inebriate. The character of the pulse is the *only indication* of this morbid condition. Dr. F. A. Mohamed says: "The pulse presents the signs usually recognized as those of high tension; the most important character to be recognized by the finger is that of *persistence*, the vessel being constantly full during both systole and diastole."[1] *The urine is normal.* Sir William Gull and Dr. Sutton have recorded "a series of observations on the

[1] Trans. Pathological Society of London, vol. xxviii. p. 394, 1877.

morbid state commonly called chronic Bright's disease with contracted kidney, and affirmed that there are, (1) not only the well-recognized, and, we may say, notorious cases in which the kidneys are contracted, the heart much hypertrophied, and the vessels diseased, but there are (2) others in which the kidneys are but slightly affected, and yet in which the heart is equally hypertrophied and the vessel diseased, and (3) other cases in which the heart is hypertrophied, the vessels diseased, but without disease of the kidney of the kind in question, or merely the congestion of the dying. In all these three classes of cases we have observed fibroid changes in the arterioles, capillaries, and interstitial tissue of various organs. On these grounds we expressed the opinion that the pathology of the state commonly called chronic Bright's disease with contracted kidney was not essentially renal, and that for its full comprehension a wider investigation of concomitant or even antecedent changes in other organs was called for. Since the time named we have prosecuted these investigations more or less continuously throughout the several organs, stomach, spleen, liver, lungs, heart, cord, brain, skin. If further inquiry should establish, as it seems to us assured that it will, that, after the middle period of life, there is very commonly a pathological condition of the body which leads to fibroid changes, not only in the kidneys, but more or less generally in other organs, then we may conclude that the renal affection, being of the same kind and character, is probably but a more pronounced local expression of a general disease or degeneration."[1]

A knowledge of this disease, including the conditions under which it originates, and its pathology, is certainly of very great importance, without which a dangerous surgical complication would be overlooked. The fact that no examination of the urine can afford any aid in making the diagnosis—that the character of the pulse alone must be depended on without any other corroborating symptoms to establish the existence of a disease in which grave pathological changes are constantly

[1] Ibid. p. 361.

taking place—gives additional interest and importance to the study of the conditions under which the disease originates. The danger attending the performance of surgical operations on patients suffering with any form of degeneration of the visceral organs will depend, not merely on the existence of the disease, but will generally be proportionate to the extent of the pathological lesion and the amount of functional disturbance arising from the same. These conditions are not alone dangerous to life, but they frequently defeat the objects for which the operations were performed, although the patients may linger months with an unhealed wound and finally die as soon, or sooner, than if the operation had never been performed.

Since the remarks already made in regard to the various forms of degeneration apply with the same force to this disease when it is situated in the breast as when other organs are affected, it is therefore unnecessary to comment specially on it here, further than to mention the fact that the administration of the anæsthetic should be more cautiously performed under these circumstances. Sir James Paget says: "I have never heard or seen anything that would make me think the administration of chloroform specially dangerous in any such patients with diseased hearts as a reasonable man would think of operating on. I have known it administered to patients with considerable valvular disease without any appearance of danger, and certainly, in any such case, the risk of chloroform would be less than that of the pain and alarm attending any considerable operation performed without it. The shock of an operation has a greater than its ordinary risk in one whose heart is feeble, or embarrassed by valvular obstruction, and those with feeble hearts will ill bear much loss of blood. But when these risks are past, patients with diseased hearts have appeared to me not prone to any dangerous complication. . . . While speaking of diseases of the heart, let me tell something of certain manners of its acting, even when we believe its structure to be healthy. People with slow pulses bear operations just as well as those who, in all other respects than those of their heart's action, are like them. And people with habitually rapid pulses are not

6

bad patients if the rapidity of the pulse be not associated with some organic disease. Especially you will find a considerable number of children and young persons, chiefly sensitive girls, whose pulses are rapid enough to frighten you. Observe whether the respirations are in the same proportion rapid, if they are not, the respirations and not the pulse must be your guide in judging what is the patient's state."[1] Irregularity of the pulse, if it is not dependent on valvular disease or degeneration of the heart, ought not to be regarded as an important complication, especially in those cases in which it is habitual. Habitual irregularity of the pulse is a somewhat common concomitant of malaria. I can now call to mind several cases in this vicinity which have already been very persistent and troublesome several years; although temporarily improved by the use of quinine, I should consider this condition, in case of a surgical operation, as entitled to about the same consideration as other malarial complications. If the circumstances of the case would permit of the daily administration of about twenty grains of quinine, or some similar drug during a period of about two weeks prior to the performance of the operation, then no attention need be given to this complication, otherwise I should anticipate a moderate amount of annoyance from this source. It should not be forgotten that any disease of the heart or arteries which interferes with the process of nutrition is likely to cause more trouble in cases of operations on the lower extremities than on other parts of the body, and, therefore, prior to the performance of an amputation of the thigh, a careful examination should be made with special reference to these morbid conditions. Unquestionably, the most frequent surgical complication arising from the arteries is due to some form of degeneration, and these conditions are generally found in persons who have passed the middle period of life, and, furthermore, it is surely the case that these diseases are limited to these vessels. In most cases the degeneration of the arteries coexists with the same disease in many other organs, and it is to the widespread

[1] Loc. cit. p. 30.

character of these affections, rather than to the condition of the vessels that we should ascribe the danger of this complication. Many modern pathologists suppose that the various forms of degeneration arise from, or are associated with, an inflammation of one or more coats of the arteries, but it is not our purpose to enter on a discussion of this question here. These changes in the vessels are variously designated by different authorities.

Erichsen mentions them as follows: 1. Plastic deposits in and under the lining membrane; 2. Fatty and granular degeneration; and 3. Calcification. Dr. Francis Delafield speaks of degeneration of the arteries under the following classification: Atheroma, calcification, fatty and waxy degeneration. Degeneration of the arteries with the coexisting degeneration of other organs is undoubtedly the chief reason why amputations of the lower extremities are so generally fatal in old persons, but inasmuch as these operations are not often required, and furthermore since degeneration of these vessels is generally indicated by the condition of other organs, we therefore omit the consideration of the various questions bearing on diagnosis. However it should not be forgotten in this connection that the existence of an idiopathic aneurism suggests to the surgeon an accompanying degeneration of the arteries; and no patient suffering from such a tumor ought to be exposed to the dangers of any surgical operation until the direct and remote influences of the complication have been carefully studied. The importance of the tumor itself must be carefully weighed in connection with any operation. It will not redound especially to the credit of the surgeon that he performed the operation, even if his patient soon after dies from the aneurismal complication. We naturally pass from the consideration of the diseases of the arterial coats to those which are characterized by morbific changes of the blood. Pyæmia and septicæmia are typical diseases of this class. There are important changes observed in the blood of patients dead of these diseases. The red corpuscles of the blood, even in the early stages of pyæmia, show signs of disintegrating into molecules, and are observed to be accumulated in masses without showing the slightest tendency to form rouleaux. There is a

steady increase in the number of white blood-corpuscles in the blood of pyæmic patients during the whole course of the disease in fatal cases. In all cases of pyæmia multiplex the increased coagulability of the blood may be observed in the early stages of the disease, which steadily increases as the disease progresses. In pyæmia simplex the condition is less marked, although generally present, while septic poison diminishes or destroys the coagulability of the blood. The most interesting question which the surgeon has to answer here is: Shall an amputation or any other equally important operation be performed during the existence of septicæmia or pyæmia? I am satisfied that there are certain stages in both diseases, when the performance of an operation would be worse than useless. In fact there are conditions in both diseases from which recovery is impossible, and the performance of an operation at this stage of the malady would serve no other purpose than to hasten the fatal termination.

In another stage of these diseases recovery might be possible without an operation; but the shock and the concomitant conditions arising from operative procedure would probably destroy the life of the patient. It may be safely put forth as a general rule, that no amputation, however trivial, should ever be performed in any stage of pyæmia multiplex. This opinion is supported by the following facts: 1. No amputation performed after the formation of metastatic abscesses can remove the danger arising from purulent absorption, or from the absorption of the products of decomposed pus. 2. It is nevertheless possible to remove all danger arising from absorption connected with open wounds, by a strict adherence to the rules of antiseptic treatment, but it is not possible to prevent all the troublesome complications arising from amputations. In mild cases of pyæmia simplex an amputation may be proper, and should be occasionally performed; and the same rule is equally applicable to septicæmia. The operations performed during the existence of septicæmia in former times were undoubtedly justly regarded as *especially dangerous* on account of the strong probability which existed, that the patient would receive into his system a second dose of septic poison while still bur-

dened with the first; but this danger is no longer feared by those who have had an opportunity of watching and carefully studying Mr. Lister's Antiseptic System of Wound Treatment. The question of amputation frequently arises when the patient is suffering from traumatic erysipelas or a spreading cellulitis. In these cases it may be very easy to demonstrate that this complication greatly increases the danger attending the performance of an amputation, and that in certain cases no operation should be performed; and further, that in other cases it should not be omitted; but it will be found very difficult, if not impossible, to formulate any accurate rules for the guidance of surgeons in this disease, nevertheless many of the comments on pyæmia and septicæmia are also applicable here. It would generally be in chronic cases that the surgeon would think it justifiable to perform an amputation, and even then before proceeding to the performance of this operation, he ought to be satisfied, from frequent examinations of his patient, that the various organs of the body are performing their functions comparatively well. There still remains for our brief consideration in connection with operative surgery, another condition of the blood which is designated by the term anæmia, and which implies a deficiency of this fluid, or, more correctly, a diminution in the ratio of the red corpuscles. This condition, which is closely allied to general debility, cannot be properly regarded as a disease, but only as a symptom, and whether favorable or otherwise to the performance of an operation, will depend entirely on the morbid conditions from which it takes its origin, or with which it is found to be associated. In all those cases where the anæmia is entirely dependent on that chronic disease of the knee-joint, commonly called "white swelling," the patient quickly recovers after an amputation of the limb, unless there are other complications. The sufferings of the patient, and the tax on his strength, due to the more or less profuse suppuration from the diseased parts having both ended with the operation, the amputation wound may now be expected to heal kindly.

In another class of cases, where the anæmia arises from frequent losses of blood from the uterus, or repeated secondary

hemorrhages from ruptured arteries, the patients make a somewhat slow recovery. Sir James Paget has called attention to the fact, that a late secondary hemorrhage itself implies a defect in the healing process. Let us now pass from anæmia to the opposite condition, plethora, and here we cannot do better than to cite Sir James Paget again, who says on this subject: "Plethora, pure and simple, is not a bad condition for operations. As far as I have seen, people that have been full-blooded, ruddy, warm, round-limbed, tight-skinned, with strong hearts, and, as we suppose, a rather excess of blood, have done well. But such people must be carefully managed; not fed too well; not kept too long in bed; not allowed to retain refuse; and mere bigness must not be taken for plethora."[1] This condition is often associated with over-eating, which "is not commonly supposed to lead to any such risks of life as over-drinking does; yet I believe that you will find, in operative surgery, that among the habits that increase the danger to life, this may stand not far from drunkenness, especially if the over-eating is of meat and other nitrogenous foods. I am led to believe this from several cases that I have observed, and I think that there is abundant evidence of it. You know that the general results of operations in provincial hospitals tell of a smaller mortality than in the hospitals of London and the larger towns. The difference is commonly ascribed to differences in the purity of the air, and other advantages of that kind in the comparatively rural districts. I believe much more of it is due to the differences of habits in the several classes of patients. The differences are many; but one of the chief of them is that the poor in the agricultural districts eat far less meat than those in large towns do, and are, by comparison, less fed, though, probably, not worse fed; and you may frequently observe that patients who come to us from agricultural districts bear operations in all respects better than Londoners who are submitted to the same proceedings. Of course many things concur to make the differences of constitution between a town and a country popu-

[1] Loc. cit. p. 13.

lation; but I am satisfied that among these things a very potent influence is exercised by the difference of diet. And the differences that we mãy thus see are strongly illustrated by what one hears of the results of operations upon the natives of India and other eastern countries, whose diet is almost exclusively vegetable. Almost any amount of injury may be inflicted on them and not be followed by destructive mischiefs, which occur in Europeans under the same circumstances. They are defective, it is said, in healing power, but they recover with comparative certainty, however slowly, from operations of the greatest magnitude. A common expression about them is, 'you can't kill them.'"[1]

It is certainly very difficult to separate the evil effects of other injurious habits from that caused by over-eating. Over-eating in this country may be regarded as the off-shoot of luxuriousness. The complications arising from this condition are chiefly limited to the affluent and their favored lackeys; while the large majority of our farmers, mechanics, laborers, and servants have very little or nothing to fear from this source. It should be remembered that luxury with us gives rise not only to extravagant indulgences in the pleasures of the table, but it is also the mother of sedentary habits and other vices too numerous to be mentioned; nevertheless, there is another side to this question which should not be lost sight of in this connection, and that is, *wealth is an excellent preservative of human life*, and restricts greatly the work of natural selection. The same expression which is said to be frequently applied to the natives of India and other eastern countries, when speaking of surgical operations, *i. e.*, "You can't kill them," is also often employed by surgeons in this country in the same connection when mentioning a certain class of children familiarly called "street urchins." Among these children the work of natural selection is most thoroughly accomplished, and those who survive the hardships to which they are exposed during the first five years of life, are then prepared to endure anything within the limits

[1] Ibid. p. 16.

of human possibility. While I am convinced that the evils arising from over-eating are numerous, nevertheless, it is certainly possible to overrate them. Let us, therefore, briefly glance at some of the more direct effects of over-eating, and this inquiry may enable us to understand more readily the different bearings of this habit on operative surgery. The various conditions arising from the practice of the habit, to which I desire to direct your attention are as follows: 1. Although the digestive organs may not be actually diseased, nevertheless, the digestive functions will be found more or less impaired, and thus the surgeon will be deprived in a degree by the patient's habit of a most valuable reserve force in the case of a surgical operation, *i. e.*, the beneficial effects arising from the free employment of nutritious food. 2. The abnormal accumulation of fat whereby many of the organs are more or less embarrassed in the performance of their various functions (especially is the circulation of the blood rendered sluggish) is another condition unfavorable to success in surgical operations. 3. Unquestionably, the practice of this habit, with its allied vices, tends strongly to the production of various forms of degeneration and other diseases. It should be remembered, in this connection, that the abandonment of an injurious habit does not immediately, and in many instances never, restore the original powers of endurance. This principle is equally as applicable to the class who have been addicted to the habit of over-eating, as it is to that class who have been intemperate in the use of stimulating beverages.

Sir James Paget, after mentioning the fact that the class commonly called teetotalers are composed of reformed drunkards and tipplers, adds: "Of such people I have no good opinion when they come to be the subjects of surgery, for they seem to retain the bad liabilities of the intemperate long after they have given up their bad habits. I would not adopt the opinion that I have heard some express, that teetotalers are worse patients than drunkards; but I should always expect that a very long period of reformation would be required to free a man from the damages

he has sustained by intemperance."[1] The same author from whom we cited the above has called attention to a condition which he designates by the term "cold-blooded." This condition, although frequently observed by surgeons, has not been heretofore generally described, or carefully studied with reference to its bearings on surgical operations. This class of patients are more numerous among children and young people; but they may also be found among adults. They constantly complain of cold extremities, "and some of them feel, when you touch them, as cold as reptiles in the same climate; their hands and feet feel as moist and damp as toads and frogs. The circulation in all these cold parts is of course very slow, and probably it has not a due velocity in any of their textures; for wherever you can see vascular parts in them, they are of duller tint than they should be, dusky, and with a purple hue rather than a rosy one; and with these signs you find small pulses, and general indications of slowness in all vital processes. They digest slowly, and are very prone to constipation; and the women among them menstruate disorderly, and are liable to headaches and backaches, and a variety of nervous symptoms."[2] This class of patients make very good recoveries after surgical operations, although their condition demands the employment of tonics and an abundance of nutritious food, wine, etc. It is asserted by surgeons who have had frequent opportunities for watching these patients after the performance of operations that they are little liable to suffer from the various diseases arising from septic infection; and this is especially true when these cases are compared with those morbid conditions which have been previously described. There is another class of patients who are commonly spoken of as "*nervous;*" although entirely free from any disease of the nervous system they are fidgety, emotional, exceedingly sensitive, mobile, and excitable in both the sensitive and motor organs. Should it become necessary to perform a surgical operation on these patients, it may be anticipated that the proposition will be strenuously opposed by them and their friends.

[1] Ibid. p. 16. [2] Ibid. p. 18.

They will protest that they are too weak to endure the shock, that it will kill them, etc., but these protestations need not deter the surgeon from proceeding with the work. Sir James Paget says: "Besides, the same mobility of mind which makes these patients very fearful before an operation makes them hopeful directly after it; and amongst all the people that can in any sense be called invalids, I know none who more generally pass through the consequences of operations with impunity than do those who are commonly called nervous, and whose nervousness consists, if I may use the expression, in too great a vivacity of their whole cerebro-spinal system."[1]

Let us now briefly enter on a general consideration of the influences exerted by constitutional diseases on surgical operations. These influences will depend primarily on the disease itself, and secondarily on the stage of development which it has attained, or more especially on the pathological changes which have already taken place. The danger being least when the disease is still in an early stage of development, and becoming extreme where the great viscera are invaded by tubercle, syphilitic deposit, cancer, or other new formation. In these diseases the surgeon should not alone study the influences which the disease may exert on the operation, but also the effects of the operation on the disease, since it should be the object of all surgical intervention to confer on the patient a general benefit. A surgeon will find no satisfaction in contemplating the fact that he has amputated a leg on account of a chronic ulcer which could not be healed, when he has finally discovered that no reparation is even attempted in the amputation wound; and that the confinement and other evils attendant on the performance of the operation have only served to hasten the death of the patient, without any relief of his sufferings, although it is unquestionably true that surgical operations in certain conditions of constitutional diseases are often permissible, frequently useful, and sometimes indispensable. The result of these operations must generally depend very much on the nature of the

[1] Ibid. p. 20.

constitutional disease from which the patient is suffering. In all the varietes of cancerous affections the melancholy fact that complete and lasting beneficial results are not generally obtained must be admitted. The reparative process in this disease remains good, except in those cases where the visceral organs are involved; and wounds resulting from amputation of the limbs will readily heal. Constitutional syphilis without visceral complication may be expected to retard the healing process, but the importance of this diseased condition must be estimated by the degree of injury already done to the vital powers of the patient, inasmuch as there is no special danger arising from the disease in surgical operations. This class of patients are often greatly benefited by a preparatory course of treatment, but if this has been neglected prior to the performance of the operation, then suitable medicines should be administered as soon after it as may be practicable. What has already been said of constitutional syphilis is equally applicable in cases of scrofula. Sir James Paget says on this subject: "Scrofulous patients, whether old or young, have, I think, no special liability to the fatal consequences of operations, except in so far as they are feeble and may die (though they rarely do) through slow exhaustion, or the gradual development of some internal organic disease. The relief from pain and the removal of irritation commonly seem more than enough to compensate for the shock and other depressing influences they are at first submitted to. They seem not very liable to pyæmia, erysipelas, or other of these sore plagues. All this you may see often enough in our cases of excision of joints; and in these same you may also see better than in any others, what are the defects of the scrofulous constitution in reference to recovery from operations. The wounds heal very slowly; the cellular tissue is apt to become very 'œdematous and gummy;' the scars are thin, and often break down and ulcerate; the deeper cuttings become sinuous, with tedious discharges of thin pus, and wasting. In a word, the half-healed wounds are apt to become like scrofulous ulcers; and if the patients remain long uncured, their constitutional scrofula is increased by long confinement, and perhaps by hos-

pital-air. That, you may sometimes find (but it ought to be in a small minority of cases) that scrofulous patients seem to be, if I may so speak, made more scrofulous by the removal of a diseased limb or joint. And this is, no doubt, the explanation of some of the cases which have led to a belief often entertained, that the removal of scrofulous disease from one part induces its occurrence, or aggravates it, in another. There are, indeed, some cases, especially among the middle-aged and older, in which the two events do seem to stand in direct relations. You may have seen last year a girl in Sitwell, whose forefinger was removed for scrofulous disease of one of its joints. The wound had scarcely healed before similar disease ensued in a knee-joint, which was sound before the removal of the finger. So I have seen a patient, one of whose toes was removed for scrofulous disease; then a knee became similarly diseased, and the limb was amputated above it; and soon after this caries of part of the spine ensued. Recovery from this last disease has been followed by no further outward appearance of scrofula. Such sequences, however, are not to be certainly ascribed to the operations. Recently, a patient long under treatment, with scrofulous disease of the elbow, and with the sinuses healing, has had scrofulous disease of the spine, and this has seemed to advance while the disease of the elbow has improved. The study of the relation of these successions of similar diseases in different parts is one in which you may do good and gain honor; but the event is so far infrequent that, except in the intensely or the acutely scrofulous, or those who are not young, you need not fear it. In the large majority of cases, especially the chronic cases, the removal of a scrofulous part is followed by improved health. Still, remember, the operation is finally effective only against that part; the patient may remain scrofulous, and may need the same constitutional treatment after, as before, the operation. Therefore, before you operate, make sure, if you can, that the patient, especially if he is old, is one who can stand prolonged confinement. Have this in mind when you have a choice between two or more operations; and, after the operation, take care that the patient's general condition is helped with fresh air

and fit food and cleanliness and all other good means that you can provide. The scrofulous patients of whom I have been speaking are such as may be considered very liable to tuberculous disease, though having none actually present, at least in any internal organ."[1]

A careful examination of the effect of constitutional diseases on surgical operations confirms the opinion that these operative procedures are more frequently palliative than curative; although they are unquestionably sometimes highly useful. In certain cases they may prolong life by removing the direct cause of danger; in other cases by affording time for the administration of proper remedies; and under more unfavorable circumstances it may be still possible to mitigate suffering, or to give hope at least to the patient. Having called attention to some of the diseases which frequently complicate surgical operations we will now enter on a brief consideration of certain hygienic conditions which unquestionably influence more or less the result of amputations. It is not our intention to furnish the surgeon in this connection with a complete hygienic guide; but to mention merely the outlines; which, it is hoped, may possibly serve to direct the thought to this subject and further stimulate investigation. Mr. Erichsen says: "There is probably no collateral branch of knowledge that has a closer and more direct bearing upon the improvement of surgical practice, as far as the lessening of mortality after operations is concerned, than hygiene; and, if I do not greatly err, it is in this direction that we ought to look for some of the greatest improvements in modern surgery."[2]

The importance of strict attention to the hygienic surroundings in cases of amputation of the limbs was clearly shown by Mr. Alanson in the eighteenth century. The writings of this distinguished surgeon prove that he was keenly alive to the dangers arising from impurities of air, soiled clothing, and foul wound dressings, while his success has rarely, if ever, been

[1] Ibid. p. 8.
[2] Hospitalism and the Causes of Death after Operations, p. 3.

surpassed. The remarks in the preface to his work, "I have *operated in thirty-five cases, such as promiscuously occurred at the Liverpool Infirmary, without the loss of a single patient.* The symptomatic fevers, the startings or spasms, the discharge, and the pain of dressing the wound, have in all been slight."[1] The vague and imperfect definitions which are given to the word hygiene are frequently a source of annoyance to authors, but it will suffice our purpose that we recognize it as that part of medical science which relates to the preservation of health, and includes the rational and methodical use of food, drink, and everything else essential to life, both in a state of health and disease. The hygienic conditions surrounding the patient both before and after the performance of the operation, will naturally influence its results. It is not my intention to dwell at much length here on the subject of food and drink. The effects arising from the intemperate use of food and drink have already been considered in this chapter with especial reference to the influence exerted by them on operative surgery, but there is still reason to suppose that the result of an operation is occasionally influenced, even in civil practice, by the insufficiency or the improper quality of the food. In military practice this complication is unquestionably a common occurrence, but since other morbific influences are generally more or less active, at the same time the part played by the food is thereby somewhat obscured and rendered less noticeable. These conditions were frequently observed by the surgeons engaged with the contending armies in the American War of the Rebellion, and the heavy mortality which followed surgical operations performed on the troops belonging to the command of General McClellan during the Peninsular Campaign of 1862, and General Grant's Wilderness Campaign of 1864, were undeniably caused, in many cases, by the badly cooked and improper food on which the soldiers had subsisted prior to receiving their wounds. It is a well-known fact that this sort of food generally causes indigestion and its attendant diarrhœa—a diseased condition very

[1] On Amputations, 1783, p. 15.

prevalent at times in all armies, but especially so among the new levies during an active campaign—while long-continued deprivation, or an insufficiency of vegetable food is followed by scurvy. Both diseased conditions lower the vital powers of the soldier, and unquestionably materially increase the mortality of those on whom surgical operations are performed without having first received preparatory treatment. It occasionally happens that soldiers whose constitutions are already greatly impaired by the unwholesome character of the food on which they have subsisted, are compelled to undergo severe operations, and even after the performance of the same the only available nutriment may be of the poorest quality and badly cooked. Under these circumstances the healing of amputation wounds may be either greatly retarded or completely arrested.

In some cases the wounded surfaces will be found covered with diphtheritic membrane soon after the performance of the operation, or else they will assume a gangrenous character, the diarrhœal or dysenteric complication will be probably increased in severity, and in those cases where death fails to arise from the wound itself, the patient may sink from ulceration of the intestinal mucous membrane. Mr. Erichsen says of these cases: "The mortality of operations becomes enormously increased, and there can be little doubt that thousands of deaths, which have occurred in wars between the most civilized nations, and the best appointed armies, may be attributed to these causes."[1] Let us pass from this consideration of the hygienic conditions dependent on the diet and their bearings on the recovery of the patient after the performance of surgical operations, to a study of the atmosphere by which these patients are surrounded after they have been operated on, and the hygienic effects of the same. These hygienic conditions are liable to wide variations depending on various circumstances, such as the presence or absence of decomposing organic matter, the presence or absence of sewer or other noxious gases, the size of the apartment occupied by the patient, the number of persons breathing the

[1] Science and Art of Surgery, Amer. ed. 1878, p. 31.

atmosphere of this room, and the amount of ventilation not only possible but actually practised. It is now evident that the hygienic surroundings in civil practice will be found to differ widely from those in military camps and hospitals, and further, that there is also a marked difference between the large, airy room in the dwelling of the opulent citizen and the overcrowded wards of municipal hospitals. In the better class of private dwellings our patients are comparatively free from the various sources of contamination, although the possibility of danger from sewer gas and other causes should not be forgotten by the surgeon.

The importance of this subject is shown in the following report by Sir James Paget, who says: "One of the greatest annoyances that I have ever had was in the case of a gentleman whose prepuce I divided for phimosis. Severe it was, and necessary to be cured, I divided his prepuce and no more, neither put in a suture nor did anything that could disturb the healing of the wound. The cut was followed by swelling of the integuments over two-thirds of the penis, and very nearly the whole of the scrotum. After having done the operation, I found, on looking about for what could have caused all this misery, that the patient, although living in a very good hotel, had a water-closet in his bedroom. I had looked around the room, but carelessly, before the operation, to see whether there was anything that could bring him into mischief, and all had appeared fair. But what I had taken to be a book-case, or some article of furniture of that kind, was a water-closet, which, with the nastiness with which some London hotel-keepers provide for the convenience of their customers, had been put into the bedroom. And this is not a very uncommon thing, even in the better class of lodging-houses and hotels in London. Because every man, in coming to his room, likes to have, for cleanliness, his own water-closet, or, at least, to have one to every suite of rooms, the landlords put one at the side of a bedroom. Where a wardrobe should stand they place a water-closet, and they front it and make it look as like a decent piece of furniture as they can. It was through this scheme that the

poor fellow lost the integument of his penis and scrotum. Look, therefore, I repeat, very carefully to all the sanitary arrangements that can come within your power, even among the better class of houses and hotels."[1] The chief sources of danger to private patients after the performance of surgical operations are as follows: self-infection, arising from the putrefaction of albuminoid substances within the wound, infection from the hands or instruments of the surgeon while in the act of dressing the wound, and besides these there remains to be mentioned a faulty sanitary condition itself of the house or its surroundings. Patients in a hospital are exposed to all these dangers, but not in the same degree, although the difference is generally in the favor of the private patient at his own home.

Besides these dangers which menace the lives of surgical patients, both in private and hospital practice, there are others that belong solely to the latter. The vitiated or polluted atmosphere of the wards of a hospital has long been regarded as a dangerous enemy to those patients who are suffering from open or unhealed wounds; and it is now a well-established fact that this condition is one of the most frequent causes of septic diseases. An inquiry into the various causes of the contamination of the wards of hospitals brings out many interesting facts. It has been shown by Prof. Tyndall, and others, that the air of large cities is loaded with organic particles, and that even country air is not free from these germs. Erichsen quotes: "Parkes, who has examined the air of crowded buildings, such as military hospitals, barracks, etc., finds that it contains large quantities of epithelium from the skin and perhaps the mouth. He states that all the specific diseases may be caused by the presence of organic impurities floating in the air, and that whether these exist in the form of impalpable powder of moist or dried epithelium, or pus cells, is a matter for future inquiry. These are either absorbed by the lungs and skin, or the pulmonary and cutaneous surfaces are unable to set free their excreta in an atmosphere already surcharged; the blood becomes thereby vitiated, and low, diffuse, or erysipelatous inflam-

[1] Loc. cit. p. 67.

mations of all kinds, with pyæmia, septicæmia, or sloughing phagedæna are the necessary consequences. In fact these diseases may, if the term is allowable, be manufactured in any hospital or house, however clean and well situated, by the accumulation within it of too large a number of patients suffering from suppurating wounds. Dr. Chaumant has analyzed the air of two of the London hospitals. Besides gaseous impurities in the form of free and albuminoid ammonia, organic oxygen, carbonic acid, nitric and nitrous acids, a quantity of solid matters suspended in the inspired air, on microscopical examination (562 D.), these suspended particles were found to consist of a quantity of skin epidermis, of nucleated epithelium from the mouth, pus-cells, and minute bodies (sphærobacteria), *in active motion*, besides a quantity of fibres of clothing."[1] The facts elicited by these examinations explain satisfactorily the increased frequency of septic diseases, and the greater danger arising from them in hospitals than that which exists among private patients who have received the same injuries, and have been subjected to the same cutting operations. Furthermore, these examinations have thrown much light on the active agencies in the continued prevalence of septic diseases in the old hospitals, especially of Europe, which have been in use for centuries, and have consequently become hot-beds of infection. Faulty hygienic conditions in a hospital endanger both the lives of the patients and the reputation of the surgeons; and, therefore, duty and self-interest alike prompt them to endeavor to remove as completely as possible these existing evils, and also to adopt such methods of wound-treatment as afford this class of patients the highest degree of security. The medical profession of the civilized world seem to appreciate thoroughly the importance of hospital hygiene, and already there is much valuable literature on this subject; but since the most of the questions arising under this head are intimately associated with the various forms of wound-treatment and septic diseases, I shall therefore content myself by referring the reader to the different chapters in the body of this work in which each is specially treated.

[1] Loc. cit. p. 32.

CHAPTER III.

GENERAL CONSIDERATIONS. CONDITIONS DEMANDING AMPUTATION. CONDITIONS RENDERING AMPUTATION ADVANTAGEOUS. AMPUTATIONS OF COMPLAISANCE. CONTRA-INDICATIONS. THE PERIOD OF TIME WHEN AMPUTATION SHOULD BE PERFORMED. THE POINT AT WHICH AMPUTATION OUGHT TO BE MADE.

THE term amputation in surgery implies, when employed in its broadest sense, the separation of one part from the rest of the body; and, therefore, we speak of the amputation of the leg, finger, mamma, penis, etc., but it is more commonly used in a limited sense relating to the removal of a portion of an extremity, or the whole member. In a still more contracted sense, the term amputation is most frequently applied to that operation performed in the continuity of the bones by the aid of a saw, whilst a separation through the joints is commonly designated as " disarticulation" or " amputation in contiguity." The performance of amputation through the living tissues in ancient times was universally followed by the death of the patient, and consequently this operation came to be spoken of as the opprobrium of surgery; but the progress made in the science and art of surgery since the birth of Ambrose Paré, has completely relieved this operation from the odium which formerly attached to it. The modern surgeon now performs this operation without pain, increasing instead of diminishing the patient's chances of life and usefulness, and furthermore shortens the period of suffering. The following objects may be enumerated among those which demand, or render advantageous, an amputation:—

1. The preservation or prolongation of life.

2. Restoration to that condition which will enable the patient most readily to procure a livelihood.

3. The removal of unsightly deformities, the relief of pain, or the accomplishment of some other equally necessary purpose, *which cannot be effected by a less dangerous or more desirable operation.*

Having before us the objects which we should endeavor to obtain by the performance of an amputation, we may now enter on an examination of the various conditions which supply the indications for operative procedure. The fact that the preservation or prolongation of life under all circumstances, is entitled to the first place in every consideration involving the question of amputation, enables us to assert that the absolute indications for the performance of this operation are such diseases or traumatisms of the extremities as *are incurable by any other means*, and which, because of their *severity*, and the patient's *condition* or *surroundings, endanger his life.* Surgeons now unanimously agree that in these cases amputation is *demanded;* and the plea is no longer offered that it is better a limb should drop off as the result of gangrene arising from a traumatism, than that it should be cut off. In other conditions amputation may not be demanded, but nevertheless it may be advantageously performed, since it will enable the patient more readily to earn a livelihood. In this way an incurable ulcer of the leg, involving the whole circumference of the limb, and further complicated with caries of the bones, which produces hectic fever or some other form of constitutional trouble, thus thoroughly incapacitating the patient from labor, may call for the performance of this operation. It should be remembered here, that the present perfected state of the artificial leg, enables its wearer to perform many kinds of labor with much success and comparative ease. The loss of a leg need no longer be dreaded on account of its pauperizing effects on the patient; but the loss of an arm cannot yet be so well supplied, in fact this artificial limb is still much more ornamental than useful. Prior to the performance of amputation for the purpose of obtaining the object indicated in the second order of our classification, there should be a very careful exami-

nation into the patient's present physical condition, the probable effect of this operative procedure on his sufferings, ability to earn a livelihood, and in fact every possible bearing of the case. While this consideration is progressing it may even be proper to ask if there are not certain forms of disability that may arise either from injury or disease in which the mere possession of vitality ought to be adjudged worthless. The performance of an amputation belonging to the third order of classification ought never to be undertaken without *carefully weighing the advantages to be attained and the dangers to be feared.*

Deformities are only relative, not positive, indications for amputation. Fortunately the advances made in the department of orthopædic surgery during the last century have caused amputation to be almost completely abandoned for these deformities. Formerly certain forms of club-foot and anchylosis of the knee-joint were generally recognized as supplying an indication for this operation, but surgeons now succeed in effecting a cure without the loss or mutilation of any portion of the limb. It nevertheless follows as a matter of course that an anchylosis, pseudo-arthrosis, supernumerary part of an extremity, or a contraction arising from a cicatrix, may call for the performance of an amputation, but *this should never be done when the object sought can be accomplished by a less dangerous or more desirable procedure.* The study of these deformities with reference to an operation, is sometimes seriously embarrassed by the importunities of the patient, and the surgeon, unless possessed of much firmness, which should be based, in all cases, on a thorough scientific investigation, will be generally too much influenced to to act judiciously. No surgeon should perform an amputation of complaisance without professional advice, unless thoroughly self-reliant, and even then if a single doubt exists in his mind in regard to the propriety of the same, the rule should be to abandon or postone all further action.

M. Velpeau says: "As a general rule, a discreet physician ought in such cases to resist the entreaties of persons who consult him. There is evidence, in fact, to show that the operations which are denominated those of complaisance terminate

sufficiently often in an unfortunate way. In 1821 there was received into the Hospital of St. Louis a man of robust make, in the vigor of age, and in other respects enjoying the most flourishing health, but with the firm resolution of having his thigh cut off for an anchylosis of the knee, which obliged him to use a crutch. After having remonstrated with him in every possible way, and traced out to him as black a prospect as could be portrayed of the dangers to which he would be exposed, M. Richerand finally acceded to his entreaties; the amputation was one of the most simple; no local accident oceurred; but an ataxic fever, which soon supervened, ended, nevertheless, in death on the fifth day. Pelletan cites a similar fact. I saw some quite as striking at the Hospital of Tours, from 1815 to 1820, and M. Gourand, then surgeon-in-chief of that establishment, finally came to the resolution, as Dupuytren did afterwards, of giving a flat denial to these pressing requests of patients. In 1825 a countryman, who had been an old soldier, annoyed at having a large leg, and carrying a dry ulcer (ulcère sec) behind the malleolus, presented himself in the wards of the School of Medicine, with the idea of having his limb amputated. It was in vain that M. Roux endeavored to alarm him, and to make him feel the rashness of his project; nothing could shake him. The operation presented nothing peculiar; the first days went off as well as could possibly be desired; but constitutional symptoms supervened, and the man died at the end of the week. What is worse, amputations of the least importance in themselves, those of a finger or toe, for example, have not unfrequently been followed by similar results. In 1829 there was received in the Hospital of St. Antoine a shoemaker whose left forefinger had been for a long time held firmly and immovably fixed upon the palm of the hand. I operated upon him, and this patient, who did very well at first, and finally recovered, was, during fifteen days, so severely affected, that on two different occasions I thought there was no hope for him. A young peasant girl came into La Charité to have an amputation of her left forefinger, which was retracted backwards, and adherent to the dorsum of the metacarpal bone; she died

of phlebitis and of purulent peritonitis on the eighth day after the operation. Nothing is more common than examples of this kind, and there is no practitioner who has not had occasion to see them. From thence has arisen a question among modern observers which the ancients seem never to have thought of: Ought a practitioner to limit himself to simple explanations? Is it not his duty positively to refuse to perform operations which are not indispensable? At Paris many surgeons have answered negatively, and violently oppose those who amputate under such circumstances. For myself, I find the question badly stated, and here is another one which may be brought into consideration: Does humanity allow that we should condemn a man to carry forever an infirmity which renders life a burden, merely because that in the attempt to get relieved of it, he may be exposed to more or less serious dangers? . . . Far be it from me to justify those who are in haste to perform amputation of the limbs for lesions which do not absolutely require it, and for simple annoyances, and merely because the patients wish to be relieved of them; but I would ask if it be not conformable to a sound surgery to have recourse to it for deformities which we cannot otherwise get rid of, when those deformities are of a character to destroy the natural uses of an important part of the body, to give rise to pains, and to make them a source of trouble and continual suffering, and when the patient also has decided upon it, and maturely reflected upon the consequences which may result from determination?"[1]

There is abundant evidence to show that much importance has been attached by some authors to the arguments formerly offered against amputations of complaisance; but there is *no reason to suppose* that the results are less favorable in these operations than they would have been on the same subject had the preservation of life been the object which prompted the operative procedure. We think a careful examination of all the reports and arguments bearing on this subject must nevertheless convince any unbiased surgeon that these operations are

[1] Operative Surgery, ed. by Mott, vol. ii. p. 460, N. Y. 1851.

both *justifiable and humane;* but before commencing operative procedure there is a very important question which must be settled in each case on its own merits. Let the surgeon therefore answer this query: Will the advantages accruing from the operation compensate the patient for the danger, pain, and inconvenience attendant on the performance of the same? Having already examined the objects gained by amputation in connection with some of the indications for the performance of this operation, we will now mention some special conditions requiring this operative procedure. These conditions are so varied, numerous, and often complicated, that I shall make no attempt at their classification further than I have already done. I have previously employed such adjectives as general, absolute, and relative in expressing the character of an indication for amputation. Prof. Bardeleben has suggested that these indications may be classified in the same manner as the diseases which have rendered necessary the performance of the operation and in the same manner as surgical diseases are classified, which is as follows: 1, disturbance of nutrition; 2, deformities; and 3, injuries. We are unable to discover in this classification any special merit; and the fact that many of the worst cases of disturbed nutrition with which the surgeon has to deal arise from injuries would certainly be an argument against it. It must be further admitted that no system of classification, adherence to fixed rules, or knowledge which may be obtained from a report of cases will ever be so perfect as to enable a surgeon to determine with mathematical certainty the propriety of an amputation under all circumstances. In some cases an experienced surgeon may be able to reach the conclusion that an amputation ought to be performed at a particular stage of a disease, which only a few days previously was not indicated. In certain cases the preservation of life may have seemed impossible without this operation, but this was neglected, and nevertheless recoveries have taken place. Modern progress in diagnosis has greatly diminished these uncertainties, but still it must be acknowledged that absolute certainty in the practice of surgery, even in this particular, is not possible, therefore it is of the greatest importance

that the surgeon should be familiar with the idiosyncrasies of the patient as well as the disease or traumatism and all other existing complications.

The following conditions may be regarded as indicating amputation subject to the rules already mentioned. 1. Extensive suppuration and destruction of the subcutaneous and intermuscular tissues, which, if the entire diseased parts are not removed, may be expected to end in death. 2. Old ulcers supply only a relatively strong indication for amputation even when it has been shown to be impossible to heal them, or, where they cripple and incapacitate the patient so much as to prevent him from earning a livelihood. 3. Elephantiasis, a leprous degeneration of the skin and cellular tissue, when it involves a considerable portion of the limb and cannot be cured by external or internal remedial agents. 4. Aneurisms which, because of the size of their sacs, the suppuration or gangrene of the soft parts, or caries of the joints, would not be benefited by ligation. 5. A very large atheroma which because of its broad base or peculiar situation will not admit of extirpation or any more desirable method of treatment. 6. Medullary sarcoma of the soft parts which ramifies between the muscles. 7. Any disease or injury of an extremity which is in itself an incurable affection and which is attended with positive danger to the life of the patient, renders amputation absolutely necessary. We have recourse to it as the safest means. We remove the cause in order to avoid the consequences. 8. Any large lacerated or contuso-lacerated wound with loss of substance, injury to the large vessels and nerves, and uncovering the bones. 9. Hemorrhage which cannot be controlled by any other means. 10. Caries or necrosis of the bones of the extremities should be regarded as indicating amputation when the disease endangers the life of the patient, or after it has destroyed the usefulness or rendered burdensome the limb; *unless these evils can be obviated by the performance of a more desirable or less dangerous operation.* Caries involving the large joints may call for amputation when so much destruction has been accomplished by the disease as to preclude the possibility of remedying the evils by resection. Internal necro-

sis involving the tubular bones, especially certain parts of the femur and tibia where the sequestrum is so situated that it cannot be removed on account of its surroundings, may demand amputation. 11. Other morbid conditions involving either primarily or secondarily the osseous tissues, such as osteo-chondroma, osteosarcoma, osteoma, ostitis interna granulosa seu fungosa, fungus medullaris, or an aneurism of the periosteal artery, may require an amputation in accordance with the *general rule.* 12. If a portion of an extremity is completely or almost completely cut or torn off amputation should be performed immediately. Injuries of the fingers, however, form an exception to this general rule. In cases of simple incision where only a slight band of the soft parts remains, the surgeon should always make an attempt to save the whole finger by adjusting neatly the parts, and applying an immovable bandage, but should there be complete separation then the parts should be properly cleansed and a suitable dressing applied. 13. An extensive comminution of the bones of an extremity with a corresponding injury of the soft parts, in which condition it is evident any attempt to save the limb will seriously endanger the life of the patient, and when the best possible result without amputation must end in preserving an unserviceable member. These principles are also applicable to those injuries in proximity to the joints of an extremity, which cannot be remedied by the performance of resection. 14. Compound dislocations when complicated with severe lacerations, large openings into the joints, or extensive comminution of the bones, if resection is not admissible, may require amputation. 15. Among other local traumatisms which occasionally require amputation may be enumerated burns and frost-bites. The surgeon being satisfied that the injury has completely destroyed the circulation beyond the possibility of restoration in a portion of an extremity should immediately proceed to operate, unless there exists some contra-indication in that particular case. 16. The bite of a rabid animal, or a venomous reptile, may possibly justify the amputation of a finger or toe, *provided always* that this operation can be *performed so promptly as to be certainly efficacious.* We have now

presented those conditions which are generally regarded by the most eminent surgical authorities as supplying indications for the performance of amputation of the extremities. Some of these indications may arise from gunshot injuries and others may have their origin in disease. In fact the necessity for amputation does not depend on the etiology of the disease or injury, but on the character of the lesion and the surroundings of the patient.

Recoveries from compound fractures in private practice frequently occur, in which the same injury under certain circumstances in military practice could only terminate in death. Every active campaign furnishes abundant proof of the truth of this statement. The number of surgeons, compared with the number of wounded, in all the principal engagements, is comparatively small; and, therefore, it is impossible for the injured to receive that *prompt* and *careful* surgical attendance which is not alone desirable, but frequently determines the question of life or death. The most desirable surgical appliances, or the best remedial agents may not always be at hand, and it is under these circumstances that the military surgeon displays his fitness for his position, where knowledge and presence of mind enable him quickly to take advantage of every accident. He applies the best remedy within his reach, instead of waiting for something better, which cannot always be obtained. The exigencies of an active military campaign permit only the most important apparatus, that the army may not be burdened with a large amount of hospital stores. The various incidents arising in connection with these campaigns, and inseparable from them, give exercise to the judgment and ingenuity of the army surgeon. The enemy may capture the hospital stores, detached positions of the army may be engaged many miles away from the main body, or defeat may compel the entire army to retreat, while a proper sense of duty impels every soldier to take with him the wounded; and all these circumstances must necessarily influence the action of a surgeon in selecting the cases on which he will perform amputation. It requires only a slight experience to satisfy a surgeon that the transportation of a case of

compound fracture of a lower extremity in an ambulance is always attended with much suffering and danger; and whether the patient will live or die ordinarily depends on the duration of this process, while those who have had these limbs amputated endure this hardship much better.

Having already examined some of the various indications for amputation, we are now prepared to glance at the contra-indications. The CONTRA-INDICATIONS are of two sorts, and are based on different conditions. The one class indicating that the operation should be *permanently* abandoned, and the other that it should be *merely* postponed. An incurable constitutional or local disease, when it has reached a stage in its development, which enables the surgeon to say that the patient *will either die during the performance of the operation*, or, should he survive, it is nevertheless *certain* that he *will not be benefited* by the operative procedure, should be regarded as an *absolute* and *permanent* contra-indication. As types of these contra-indications may be mentioned phthisis, cancer, and chronic Bright's disease. No prudent surgeon will recommend an amputation of an extremity, unless satisfied that the advantages to be gained are sufficient to compensate for the dangers and inconveniences to be sustained. The contra-indications which demand the postponement of an amputation are numerous, and may be any condition or disease, which, at the time, would endanger either the life or well-being of the patient, should an operation be now performed; but which may be so far remedied that the same operative procedure may take place at some future time under more favorable circumstances. Among the contra-indications which require *this* postponement may be mentioned a vitiated condition of the atmosphere in which the patient will remain after the operation has been performed. It is a well-known fact that this contamination of the air may arise from a variety of causes, such as sewer-gas, the decomposition of animal matter, the overcrowding of surgical wards, etc.

Ordinary prudence would forbid that a surgeon should perform an amputation on a patient suffering with pneumonia or other acute disease, except under the most urgent circumstances.

The above remarks are especially applicable to patients suffering with erysipelas or any form of septic infection, *even the existence of these diseases* in the same ward with those requiring an amputation must be regarded as a contra-indication, and one which commonly calls for the postponement of the operation. Shock is another condition which frequently calls for the postponement of an amputation. The above references to contra-indications are only intended to serve as beacon lights for the benefit of the surgeon in his consideration of the question of amputation, but closely allied to it is the PERIOD OF TIME WHEN AMPUTATIONS SHOULD BE PERFORMED.

When a traumatic lesion has rendered the performance of amputation absolutely necessary, it then becomes important to determine the most favorable time for the accomplishment of this object.

This question is not new, has frequently been the subject of protracted discussions, and it was not until the present century that any unanimity of opinion could be claimed to exist on this point among surgeons.

Military surgeons were the first to advocate the immediate performance of this operation, as is shown by the writings of Wiseman, Rauby, and Le Dran.

Rauby says: "If a wound be of such a desperate nature as to require amputation (which is always the case where it happens in any principal joint), it would certainly be of consequence could the operation be performed on the spot, even on the field of battle; but, by deferring it, an inflammation may come on, which one may very reasonably expect should obstruct a work that ought rarely to be entered upon during the continuance of so calamitous a circumstance. The neglecting this critical juncture of taking off a limb, frequently reduces the patient to so low a state, and subjects the blood and juices to such an alteration, as must unavoidably render the subsequent operation, if not entirely unsuccessful, at least exceedingly dubious."[1]

The French Academy of Surgery proposed this question as

[1] Chelius's System of Surgery, ed. by South, vol. i. p. 380.

the subject for a prize essay in 1755, and again in 1756. This discussion was participated in by Faure, Leconte, and Boucher. The Academy awarded the prize to Faure, and have therefore been accused of deciding in favor of delaying the operation whenever practicable, although from the first it was absolutely necessary. This accusation is, however, shown to be unjust by the exceptions noted in Faure's paper. Faure thought that an amputation performed immediately or very soon after the receipt of an injury would be dangerous, because nature seems to demand that an operation of this importance which produces so much disturbance of the natural function of the animal economy should never be done during the period of the most violent agitation, and while the patient is in the highest state of bodily excitement. He admits only of exceptions in the following cases: 1. When the limb has been torn from the body; 2. When a comminuted fracture involves a large articulation, whether caused by gunshot wound or otherwise; 3. When an extremity is almost destroyed, the bone being extensively comminuted with considerable loss of the soft parts; 4. When the bones are extensively comminuted and the adjacent tissues are injured and contused with destruction of the tendinous and aponeurotic structures; 5. If a fracture involves an articulation even in the slightest degree with a considerable destruction of the ligaments of the joint; 6. Hemorrhage from an arterial trunk of an extremity which endangers the safety of the patient and cannot be controlled except by amputation.

Leconte, a physician of Arcueil, advocated the same ideas in his memoir which received an honorable mention, and was published in the collection of prize essays by the Academy of Surgery. Boucher argued in favor of immediate amputation, and justly claimed that delaying an amputation made necessary by a traumatic injury exposed the patient unnecessarily to the dangers arising from inflammation, gangrene, diffuse suppuration, purulent infection, and tetanus; thus destroying many lives which could have been saved by a prompt operation. This opinion expressed by Boucher has long since prevailed among French surgeons, who have unanimously pronounced in favor of imme-

diate amputations. Dubor, cited by M. Velpeau, asserts that the French surgeons during the American Revolution in 1780, lost nearly all their patients on whom they performed any amputation, although the American surgeons who performed the same operation on the field saved nearly all their cases. There is conclusive proof that the English military surgeons, even while the French Academy of Surgery were debating the question of immediate amputation, continued to advocate and practise it in their armies.

Dr. Hennen says: "It is but justice to British surgeons, both naval and military, to declare that immediate amputation is neither a new doctrine nor a recent practice among them. How long it may have been in use in the former service I cannot undertake to say, but every naval surgeon with whom I have conversed informs me that he always employed the knife where its use was indispensable, *at once*, which implies a much earlier opportunity than army surgeons can possibly enjoy. To advert to the experience of our service in the late wars: surgeons who served in 1794 on the Continent assure me that the greatest benefit resulted from immediate amputation, which they had recourse to wherever they possibly could. I have the authority of my friend, Dr. Pitcairn, deputy inspector of hospitals, who served as surgeon on the staff of the Egyptian expedition, to state, that whenever the surgeons could operate upon the field in that country they did so, and, for himself, he only lamented that he could not remove more limbs in that situation, having never had any doubt upon the point, and being still more confirmed in the justice of his opinion by the results of the deferred operation. On the first landing of our troops in Portugal, the propriety of the practice was impressed upon the surgeons, as I have been informed by Mr. Gunning, then senior surgeon upon the staff, and subsequently surgeon-in-chief of the Peninsular Army; the practice was constantly followed, and the precept orally delivered from surgeon to surgeon during the whole period that I served in that country, and the able work of Mr. Guthrie forcibly elucidates its propriety; while the utility of the same practice, as adopted by the French, is fully shown by

M. Larrey. Finally, the results of the field amputations, after the battle of Waterloo, confirm the published experience of both these writers, and it is to be hoped that the question is now set at rest forever."[1]

These views were not shared by Mr. Hunter, who, in writing on this subject, remarks: "Nothing can be more improper than this practice,"[2] and he then proceeds to assign his reasons, which have long since been shown to be fallacious. The opinion here expressed by this distinguished surgeon had very little influence on military surgeons, and they merely deigned to answer by asserting that civil surgeons were not in such a position as to enable them to form a correct opinion of the advantages of primary amputations.

Erichsen says: "In military practice, secondary amputation is, in general, more fatal than primary. Thus, Faure saved only 30 out of 300 secondary amputations, whilst Larrey saved three-fourths of those in which he amputated primarily. In the Peninsular War, the mortality after secondary amputation of the upper extremity was twelve times, and after secondary amputation of the lower limb three times as great as after primary amputation of these parts. In the British army in the Crimea, from the 1st of April to the close of this war, the relative rates of mortality, per cent., after primary and secondary amputations, were as follows: after *primary* amputations at the shoulder, 26; of the arm, 17; of the forearm, 3; of the thigh, 62; of the leg, 30; and of the foot, 17; after *secondary* amputations at the shoulder, 66; of the arm, 31; of the forearm, 28; of the thigh, 80; and of the leg, 76. Or, for the upper extremity, the whole rate of deaths after primary was 15, against 41 after secondary amputations; whilst for the lower extremity, excluding the foot, it was 46 for the primary against 78 per cent. for the secondary. In the American army during the War of the Rebellion the mortality after primary amputation of the thigh was 54.13 per cent., and after secondary amputation, 74.76. In the French

[1] Principles of Military Surgery, Phila. 1830, p. 55.
[2] On the Blood, Inflammation, and Gunshot Wounds, Phila. 1841, p. 538.

army in the Crimea, on the other hand, the mortality after primary amputation of the thigh and arm, amounting in the former limb to above 90 per cent., was greater than that after the secondary operation. As has already been observed, not only does the *rate* of mortality differ in primary and secondary amputations, but also the *cause* of death. Primary amputations are most frequently fatal from shock, hemorrhage, and exhaustion, although death from pyæmia and secondary disease of a low type is by no means rare in these cases. Secondary amputations for injury most commonly carry off the patient by the supervention of septic diseases."[1]

Experience, observation, and science have finally convinced surgeons, both military and civil, of the advantages of the primary amputation over the secondary; and this conclusion seems to be fully supported by statistics, but the value of these is greatly impaired by the following: 1. Irregularities in the classification; 2. Insufficient data to enable the compilers to determine the existence or character of complications; 3. Idiosyncrasy of compilers which produces interpretations of figures favorable to their own preconceived theories and opinions. The irregularities in the classification of amputations arising from the fact that one author divides this operation into four classes, which he designates as *immediate*, *primary*, *intermediate*, and *secondary;* another separates it into three classes which he calls *primary*, *intermediate*, and *secondary;* and the third still further simplifies it, and gives us in his nomenclature only the primary and secondary. The intention of all surgical writers on this subject has unquestionably been to designate by these terms pathological conditions, which it was supposed might have important bearings on the result of surgical operations. Have these authors succeeded in impressing on the minds of the majority of their readers these facts? The selection of these terms must be regarded as unfortunate, since the words themselves, as commonly employed, fail to convey to the ordinary professional mind the faintest idea of the pathological conditions, but do com-

[1] Science and Art of Surgery, 7th Amer. ed., vol. i. p. 83.

monly suggest certain periods of time. Prof. Frank H. Hamilton says: "The *immediate* period is the space of time comprised within the first few hours; and it will be convenient to establish its limit at the expiration of six hours. It refers to that condition of the general system, and more especially of the nervous system, which has been termed 'shock.'"[1] The same author says of this complication: "Shock is that condition of the nervous system which immediately ensues upon severe injuries in certain persons, characterized by coldness of the surface, pallor, and a feeble pulse; to these conditions are sometimes added tremors, a wild, anxious expression of the face, partial or comple paralysis of the bladder, and sometimes of other organs, mental disquiet or apprehension, incoherent speech, etc., which phenomena may continue a longer or shorter period, but usually, unless the shock is severe, they disappear in a few hours. When the accident is of a more grave character, no reaction occurs, and the patient dies immediately, or within a short time. In general it may be said, that if reaction does not occur within twenty-four, or at the most forty-eight hours, the patient will die. In some cases the occurrence of the shock seems to be delayed, the depressing influence of the injury not being felt until some little time after. . . . Surgeons who hold to the frequent occurrence of delayed shock, recognize in this an argument in favor of 'immediate' amputation in a great majority of cases; and certainly, assuming the premises to be correct, the argument seems not unsound. Says McLeod, 'If this precious moment could be seized at all times, and that operation performed, under chloroform, which assists so much in warding off the 'ebranlement' we fear, how much more successful would our results prove than under other circumstances they can ever be.' . . . Larrey, indeed, seemed to regard amputation as the proper remedy for this peculiar condition of the nervous system. 'I have lost,' said he, 'a great number of soldiers, because, although operated upon within the first twenty-four hours, yet the operations had been made too late.'"[2]

There is a possibility that shock may in some instances be

[1] Principles and Practice of Surgery, p. 340. [2] Ibid. p. 341.

delayed; but these occurrences are unquestionably rare, and the cause of such delay is generally revealed by an autopsy. My own observation and study of this condition are strictly in accordance with the views expressed by Prof. Hamilton when he says: "For ourselves, we confess that we have never met with these examples, except when some visceral lesion, or the rupture of a large bloodvessel has accompanied the accident. It is true that men often faint after a few minutes, or after removal, and when they have had time to contemplate their situation, who seemed undisturbed at first; and in other cases, a severe and prolonged irritation from a point of bone has steadily aggravated the signs of depression and of shock; but we think these cannot with propriety be termed examples of delayed shock."[1] M. Sedillot, of Lyons, expresses the opinion that it is "the best rule to amputate on the second or third day." Prof. Hamilton says: "I must differ from him so far as to say that in general the first or second days are to be preferred, that is, the period after the shock, but within the first forty-eight hours. My own opinion upon this subject is, that amputations ought to be made in some cases immediately, or as soon as possible after the receipt of the injury; as, for example, when a limb is nearly torn off and a dangerous hemorrhage, which cannot be arrested, is occurring; or when spicula of bone, such as neither the forceps nor fingers can extricate, are causing intense suffering. In all cases of injuries to small limbs, such as the fingers and toes, immediate amputation is proper; and in a considerable number of cases of injuries to larger limbs, when it is clearly seen that the patient is not faint, or depressed, or suffering under great nervous commotion. But I cannot accept the doctrines of Paré, Wiseman, Larrey, McLeod, and others, without liberal qualifications, and a careful specification of the cases to which their rules are to be made applicable."[2]

In accordance with the views expressed by Hamilton and others, the immediate amputation differs in no essential particulars from the primary, except so far as the operation may be

[1] Ibid. p. 340. [2] Ibid. p. 342.

influenced by shock, and this condition may be entirely absent, or present in varying degrees, after the receipt of an injury during the first few hours, or even days; but its period of duration is of great uncertainty. Neither is this the only dangerous complication that must necessarily influence the action of the surgeon during the first few hours after the receipt of injury by his patient. Already attention has been called to certain forms of hemorrhage which demand the prompt removal of the injured limb, as well as other lesions which ought either to expedite or delay operative procedure. In consideration of these facts it seems to me advantageous to drop the term "immediate," and employ the word primary when speaking of any operation which has been or is to be performed, prior to the development of the symptoms, which indicate the existence of any form of septic infection. This term primary should be employed with *sole reference* to the pathological condition, and without the *slightest regard* to the lapse of time after the receipt of the injury. The necessity for adhering strictly to this rule is found in the fact that septic diseases arise in some patients much sooner than in others, while the surroundings of the case will be found to influence greatly the development of this important complication. Favorable hygienic surroundings will unquestionably, in certain cases, prevent these diseases, while in other instances it will only delay the evil day, and *vice versa.*

Another particularly important factor in cases of compound fractures and similar lesions, is the local treatment employed after the receipt of the injury. It has already been demonstrated that by the use of the antiseptic treatment it is possible in many cases, even in the presence of most unfavorable hygienic surroundings, to prevent septic infection. This fact should not be forgotten by the surgeon or neglected in his practice. It frequently happens that a surgeon is called immediately after the receipt of a severe injury complicated by open wounds; and, after having made a careful examination, finds himself unable to decide whether an amputation is *absolutely demanded* or not. Under these circumstances the surgeon should *adhere strictly* to the rules of antiseptic treatment, and having done this, and

succeeding in preventing septic infection, he may rest assured that the amputation of the limb can be performed as safely after the lapse of ten days as at the end of the first. This is certainly a very important feature of antiseptic treatment, which is applicable to the practice of conservative surgery, and it enables the surgeon to watch the restorative powers of nature, in many cases without jeopardizing the life of his patient. The same practice not only enables the careful painstaking surgeon to avoid septic infection; but even in cases where this condition is found to prevail, it greatly lessens here the danger arising from the performance of the *intermediate* amputation. Unquestionably the chief danger in this operation is due to the fact that the patient, who is already suffering from septic infection, is destined by the old methods of operative procedure to receive into his system another dose of the same poison, and in those cases where nature was barely able to eliminate the first instalment, she would be completely overwhelmed by the second. The various diseases arising from septic infection in open wounds, undoubtedly destroy more lives than all other wound complications. This fact gives a vital importance to septic infection which it is thought may justify us in designating all amputations performed during the existence of this condition as secondary operations. It should not, however, be forgotten that in some cases septic infection may have existed in connection with an open wound prior to the performance of an operation, but every trace of this morbid condition having disappeared, the operation becomes essentially primary, and should be so designated. The advantages claimed for this nomenclature are as follows: 1. It is based on distinct pathological conditions, the effects of which are strikingly manifested on the termination of amputation. 2. These conditions are not so closely allied to certain fixed periods as thereby to associate the idea of success or failure with the time when the operation was performed instead of attributing it to the condition of the patient or the existence of complications. Neither this nomenclature nor any other, which has yet been suggested, enables a surgeon to describe the condition of a patient as thoroughly as is desirable, without employing other terms

for the purpose of expressing the character of the complication, and the existing degree of lesion. Visceral lesions, whether due to a traumatism or disease, the various forms of septic infection, or the existence of shock, slight, severe, or reactionary, should be noted in connection with amputation, as well as any other complication which can possibly affect the result of the operation. It will be readily admitted that the result of an amputation, other things being the same, will depend on the complication; and no surgeon will deny that septic infection is a most serious condition. The old writers generally spoke of amputatation as the opprobrium of surgery, but modern surgeons regard the performance of this operation, under certain circumstances, as a grand surgical achievement. Had the ancients restricted the use of the term to that amputation which is commonly designated *intermediate*, but which we prefer to call *secondary*, it would certainly be accepted as more appropriate in modern times, not only on account of the great fatality attending the performance of this operation, but also from the fact that a mistake made by the surgeon at the outset frequently compels him to choose between two evils, viz., those attending the performance of a secondary amputation, or those which arise while awaiting the formation of a line of demarcation. In cases of gangrene, the formation of the line of demarcation has long been regarded by surgeons as indicating an approximation to the time when the performance of an amputation is attended with the minimum of danger. It is possible, however, that the highest degree of safety may be found after the formation of the line of separation and the development of granulations, which cover the extreme border of the living tissue. The pathological changes involved in these processes, are such as to thoroughly convince us that the increased safety in these conditions depends essentially on the formation of a barrier, which at first merely impedes, but finally arrests the absorption of septic material, and furthermore on the elimination by the natural emunctories of the poison which had already been absorbed. While it must be admitted that surgeons at all times prefer to operate on patients who are entirely free from septic infection; nevertheless,

there are circumstances under which the *amputation of a limb should be performed without awaiting a more favorable period.* The intelligent performance of this operation at such times, requires that the surgeon should determine as accurately as possible, the degree of danger which may be justly expected to arise from the contemplated operative procedure. Many important points bearing on this subject have not yet been examined with sufficient care to enable us to understand their value in this connection. How far may we depend on the temperature as indicating the danger from septic absorption under such circumstances? Are there conditions under which the poison after its absorption may remain latent in the system? No attempt will be here made to answer these queries, but it is rational to presume that in cases of traumatic gangrene, the progress of the septic infection, will in a measure depend on the rapidity with which the living tissues lose their vitality, and the extent of the disease. Rapidly spreading gangrene does not allow nature sufficient time to raise the barriers which she employs to impede the progress of this contamination, and the more extensive the gangrenous action, the greater are the number of absorbents which take up and disseminate the poison. It may therefore be claimed that the danger in cases of operative procedure from septic infection will generally bear a certain relation to these factors; but they do not constitute a basis which justifies a surgeon in supposing the existence of latent septic infection, and consequently refusing to operate in the absence of the symptoms, which indicate the existence of this danger. My opinion on this subject is in harmony with that expressed by Thomas Bryant, F.R.C.S., who says: "In a case of compound fracture, which is so bad as to suggest the necessity of primary amputation, but in which the surgeon has been desirous, if possible, of saving the limb, the first onset of an inflammatory action that assumes a gangrenous form should be met by amputation; while in a case less severe, where the injured limb has a good prospect of being made a useful one, an attack of inflammatory gangrene need not necessarily lead to

its loss."[1] Prof. Agnew says: "In incipient traumatic mortification, that which begins within what is called the primary period (from thirty-six to forty-eight hours), the surgeon should operate at once, without waiting for any line of separation, provided the patient's general condition will allow."[2]

A careful consideration of the advantages and dangers attendant on the performance of primary and secondary amputations in cases of traumatic injuries cannot fail to satisfy the most *rigid inquirer* that the former operation *is infinitely to be preferred to the latter;* and furthermore, that every operation as a general rule should be performed in these cases *as soon as possible after the receipt of the injury;* unless there exists a condition or complication which renders this procedure immediately dangerous to the life of the patient. The existence of shock in a mild form dependent entirely on an injury to a foot or hand can never justify a surgeon in *postponing an unavoidable amputation;* but should there be recognized, beside that already mentioned, a traumatism involving the visceral organs, the degree of the same not being immediately determinable, a brief delay under these circumstances would certainly be judicious during the early part of the immediate period. The surgeon, before commencing an operation, ought generally to be able to give a negative answer to the query—will the patient die before the amputation is completed?—although there are cases which form an exception to this rule. Hemorrhage in some instances can only be controlled after an amputation has been performed; and in these cases it is necessary that the surgeon should satisfy himself that the performance of the operation gives the patient the *best possible chance for life* in order to justify it, and after *having reached this conclusion, longer delay is culpable.* Neither should the application of this law be limited to cases of hemorrhage, but whenever a surgeon recognizes the fact *that the prompt performance of an amputation gives his patient the only, or decidedly the best chance for life, although this may be small, duty and humanity*

[1] Practice of Surgery, 2d Am. ed. p. 44.
[2] Principles and Practice of Surgery, vol. i. p. 134.

alike demand prompt action. Let no surgeon under such circumstances stop to ask himself what may b ethe effect of this operation on my professional reputation ; but do not forget that these remarks are only intended to apply to those cases in which the amputation is *recognized as unavoidable.* The moment the surgeon recognizes a doubt in regard to the necessity of the amputation, or the effect of the same on the chances of the patient, he should then endeavor to obtain additional information, and should he fail in this he may be justified in hesitating, postponing, or refusing to act until such time as he is able to reach a satisfactory conclusion. It must be finally admitted that no spicific rules can be given which will be found applicable to all cases of traumatism in determining the time when an amputation should be invariably performed; although general rules may be useful, still the determination of the best time for the performance of the operation is merely a question for the professional attendant; and whether his decisions will be advantageous or otherwise to his patient must always depend on his knowledge of the various questions involved in the particular case under consideration, rather than on any fixed rules.

The surgeon is controlled by the same principles in the performance of amputation for disease as in cases of wounds; but, nevertheless, time has little bearing on the results of this operation, except in traumatisms, where delay becomes dangerous, since it gives hemorrhage and septic infection an opportunity to exert their baneful influences. Having decided that the time for the performance of an amputation has arrived, we now become interested in determining the POINT AT WHICH AMPUTATION OUGHT TO BE MADE. Prof. Hamilton has put the question clearly in the following, when he says: "This will depend very much upon the part of the limb which has suffered injury; but in general we may say, amputation should be made as far from the body as a thorough removal of the injured or diseased structures will permit. In other words, we may state the rule to be, that we must save as much of the limb as possible, yet in no case should the life of the patient be put at hazard for the sake of a limb, and much less for a small portion of a limb. There are two

reasons why we adopt the rule above stated: first, because the longer the stump, other things being equal, the more useful it will be to the possessor; second, because experience has shown that the nearer an amputation is made to the body, and the larger the diameter of the limb, the greater is the danger to life."[1] The general law expressed by this distinguished author is recognized, and forms the basis of practice in every part of the civilized world, but it is necessary in each case to take into consideration in determining the point at which the operation shall be performed the character of the lesion, the advantages and disadvantages offered by each point for the application of an artificial limb, as well as its comparative danger. It is in the solution of these questions that surgeons find the most difficulty, and here is ample scope for the highest order of skill and the largest store of science. A thorough knowledge of the disease or injury which necessitates amputation is essential, that the surgeon may remove as much as is required in order to give his patient the greatest amount of safety possible under the circumstances. A few years since, a patient came under my care from whom a physician had removed the nipple and a small portion of a cancerous mammary gland, although the lady was married and only about thirty years of age. The wound healed kindly, the lady became pregnant, the pain returned immediately after the birth of the child, the breast became greatly distended with milk, and the irritation caused a return of the old disease, which necessitated the performance of a second operation. Had the entire gland, in the first instance, been removed, which is always demanded by the character of the disease for which the operation was performed, then the second operative procedure would not have been required. Prof. Theo. A. McGraw says: "The doctrine which Theirsch laid down in reference to operations on epithelial cancers, that they should be conducted with sole reference to the thorough eradication of the disease, and without any regard to the extent of the resulting wound, ought to be applied habitually to all operations for

[1] Principles and Practice of Surgery, p. 345.

malignant growths. In so doing, the surgeon must remember that infection takes place long before induration and contraction, and that integument which moves freely upon the subjacent gland may, nevertheless, be full of wandering germs. . . . I have had one case of malignant sarcoma of the lower extremity where eventual success crowned a series of operations. It concerned a man named Francis Snay, from the neighborhood of Sand Beach, Michigan. He entered Harper Hospital, Detroit, on March 1, 1872, suffering from a tumor which involved the whole right thigh, and which had, as far as I could learn, begun ten years before as a subcutaneous tumor, just above the knee. The man had been first operated on in 1869, and after that four times more before he entered the hospital. I amputated at the hip-joint, and, on the recurrence of the disease shortly afterwards, cut away all the flaps. Again the disease returned, and I cut out the scar, followed the disease up under Poupart's ligament, tied the external iliac artery and vein, and gouged out the acetabulum. I then applied to the bone and the wound, where it seemed safe, the strongest sulphuric acid. The man recovered completely, and since then has had no recurrence."[1]

In this case the first point of interest which attracts the attention of the surgeon, is the fact that the patient has survived this remarkably heroic treatment about six years, and we may safely conclude that he has lived at least five years longer than would have been possible had the operator been contented with merely amputating at the hip-joint. Another point of special interest to our profession is the view that Prof. McGraw takes of the infectious process, since it is on this that he bases his treatment. We believe that the views which he has expressed are correct, and that many of the failures following the performance of amputation for malignant disease, arise either from disregard or ignorance of these principles. We are now prepared to say that whenever an amputation of an extremity becomes necessary on account of the existence of malignant disease, the

[1] Trans. Amer. Med. Assoc., vol. xxix. p. 289 *et seq.*

operator should never fail to give the diseased parts a wide berth. In those cases where the disease is found in the feet, it is not safe to amputate at any point nearer to the diseased parts than the ankle-joint, and in some cases it may be even necessary to perform the operation at a still more remote point, should the disease be located in any part of the leg, the operation ought to be made at or above the knee, and should it involve the thigh, then the operation ought to be performed at the hip-joint. The same general rules apply with equal force to the same disease in the various divisions of the upper extremity. Let us now pass from the consideration of this question, as affected by the diseases requiring amputation of an extremity, to the same as it is influenced by the various forms of traumatic injuries. The point at which an amputation ought to be performed for traumatisms, will depend essentially on the kind, location, severity, and extent of the injury. The character of an injury in a degree depends on the agents or factors by which it was produced, and therefore it does not seem inappropriate to designate certain wounds as gunshot injuries, railroad injuries, etc.; notwithstanding the fact that we also employ such terms as incised, lacerated, contused, and contuso-lacerated. A certain class of cannon-shot wounds, resemble in a striking degree the injuries produced by railroad accidents. The characteristic feature of these wounds may be designated as contuso-lacerated, but the extent of injury is never apparent to the superficial observer. It is comparatively easy to determine the injury done to the bones, but the most careful examination will occasionally fail to reveal the full extent to which the soft parts are involved. Cases occasionally present themselves in which the external indications are very slight, or completely wanting, although the severe contusion may have done so much damage to the deep-seated tissues as to demand amputation. An injury of this kind may be caused by a spent cannon-ball, while canister-shot and fragments of shell are generally accompanied with extensive lacertions; but in these gunshot wounds, as well as in the large majority of railroad injuries, the rule and practice should be about the same in the performance of amputation, as in cases of

malignant disease; however, every case in which the surgeon is able to determine accurately the extent of the lesion, should form an exception to this rule. Of the other varieties of gunshot wounds, especially those caused by the balls discharged from muskets or carbines, and also incised wounds, which are not commonly accompanied by any injury, which renders it unsafe to amputate in the immediate vicinity of the wounded parts, Velpeau says: "On this subject, the *nature* of the disease is to be considered as well as its seat. If the question be that of immediate amputation, in consequence of shattering or extensive damage to the limbs, or wounds from fire-arms, or gangrene, inflammation and suppuration still advancing, or cancerous tumors, the instrument should be carried as high up above the apparent seat of the evil as the importance of the organ will allow. If, on the contrary, the disease which requires amputation is a gangrene defined, a necrosis, caries, suppuration, fracture, compound dislocation, wound of an artery, a division from a cutting instrument, or a strangulation, and that the morbid process which has resulted from it is purely local, and has no disposition to extend higher up, we may, without any impropriety, take away that part only which has been actually disorganized. After *traumatic lesions*, it is generally advised to amputate at the articulation, or in the continuity of the bones above it; the accidents which, under such circumstances, supervene after amputation, being most usually imputable to the cracks (or splits—félures), which extend sometimes to the spongy texture of the upper articular extremity of the bone which has been broken. M. Kerst remarks that the fissure is always made in the direction taken by the projectile. Following this indication, he has also, in cases where the wound has been made from above downward, been enabled to amputate successfully at the distance of some few inches only above it."[1]

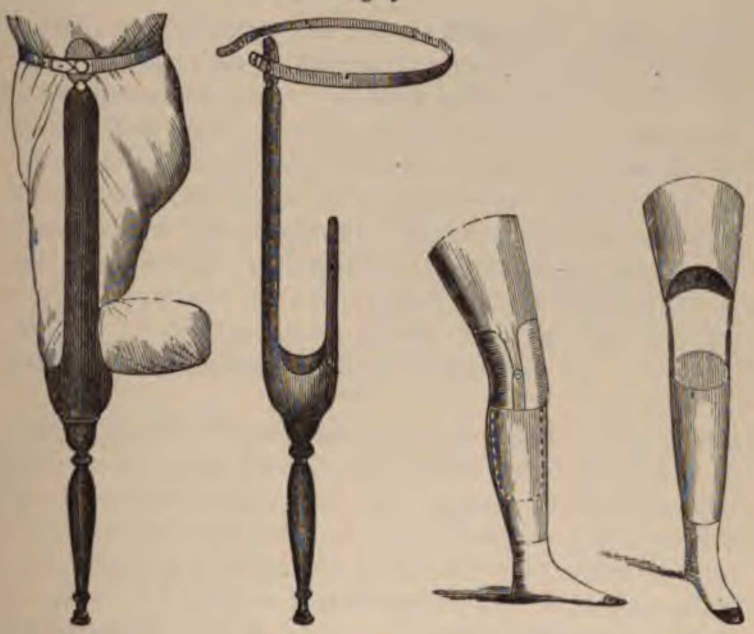
Let us now enter on the consideration of the influences exerted by locality in determining the point at which an amputation ought to be performed. Surgeons have long since learned from

[1] Operative Surgery, ed. by Mott, vol. ii. p. 472. N. Y. 1851.

observation that wounds heal *much more readily on the upper extremities* than on the lower, and they are therefore accustomed to say "we may take many liberties with injuries of the hands and arms which are strictly forbidden on the feet and legs." This peculiarity is unquestionably due to a more favorable circulation of the blood in the upper extremities than in the lower. We are therefore able to operate in closer proximity to lesions on the hands or arms than on the feet or legs; and the amount of injured tissue which may be left behind with impunity in the former instance might be followed by serious results in the latter case. The restorative powers of nature being greater in the upper extremities, it therefore follows that we find here the most favorable field for the practice of conservative surgery, including exsections which may often be performed in cases that would otherwise require amputation, and for the same reason, if a portion of a finger has been completely severed, the surgeon ought merely to apply a simple dressing and leave the rest to nature. It may sometimes be necessary in these cases to smooth off the remaining end of the injured bone, but the further shortening of the finger-stump for the purpose of covering the bone with the soft parts is generally *entirely unjustifiable.* The advantages and disadvantages offered at various points for the application of an artificial limb are less marked now than in former times. This condition arises from the fact, that mechanical skill has so far triumphed over the difficulties which were encountered in the early efforts to supply the loss of a lower extremity with something better than a bucket or peg-leg: that at this time an artificial limb can be applied to any portion of the leg with about the same facility, but the *longer the stump leverage, the greater, generally, will be the utility of the artificial appliance.* The amputation of a leg about five inches below the knee-joint, a point which was afterwards designated as the point of election, had its origin in the advantages which this site possessed for the application of the bucket-leg. It will be readily perceived, by the following wood-cuts (Fig. 5), that a long stump, since it projects too far backwards, would only be a source of

annoyance to the wearer. Besides the advantages arising from a long stump leverage, there are also two other facts which when properly interpreted teach the same lesson. It is unquestionably true that the danger to life increases with every inch the nearer we approach the trunk, and that the natural joint is

Fig. 5.



far superior for all practical purposes to any artificial joint which has been constructed. It, therefore, follows that the surgeon should select that point for the performance of amputation which is as remote as possible from the trunk, being, however, always careful that he does not here violate other equally important surgical principles. Should the leg be amputated too near a joint, it may be impossible to preserve its straightness and flexibility, because of a constant tendency to retraction and anchylosis. In the performance of amputation there is no longer any necessity, especially in this country, that the surgeon should

modify the operation in order that the patient may be able to wear the peg-leg. Even soldiers and sailors who have incurred the loss of a leg in their country's service are now supplied through the liberality of our government with good artificial limbs, and the bucket-leg will soon be regarded only as a reminiscence of the past.

CHAPTER IV.

PRELIMINARY CONSIDERATIONS AND PREPARATION. ADVANTAGES AND DISADVANTAGES OF AMPUTATIONS IN CONTINUITY COMPARED WITH DISARTICULATIONS. VARIOUS METHODS OF AMPUTATING THE EXTREMITIES—CIRCULAR, FLAP, OVAL, ELLIPTIC, AND RECTANGULAR. SELECTION AND ADMINISTRATION OF AN ANÆSTHETIC. CHOICE AND APPLICATION OF A TOURNIQUET. PREPARATION OF THE LIMB FOR THE OPERATION. SELECTION AND ARRANGEMENT OF INSTRUMENTS. THE NUMBER OF ASSISTANTS AND THEIR DUTIES. POSITION OF THE PATIENT AND OF THE OPERATOR. ARREST OF HEMORRHAGE. CHOICE AND USE OF SUTURES. DOUBLE AMPUTATIONS. RE-AMPUTATIONS, ETC.

THE surgeon having determined to amputate a limb it still remains to be settled whether the operation shall be performed in the continuity or contiguity of the bone. The determination of this question ought not in any case to be based on a fancied preference of the operator, but it should rest on sound surgical principles. The peculiar anatomical structure of the joints offers both advantages and disadvantages in the performance of an amputation. We now enter on a general consideration of this subject, but a more careful delineation will be given in a subsequent chapter in connection with the description of the performance of the disarticulation of the different joints of the extremities. The extent and character of the lesion, the adaptability of the stump for an artificial limb, as well as the peculiarities of each joint are important factors in this question which the mind of the surgeon must grapple in determining the advantages and disadvantages of each case.

I will now cite the opinion expressed by Dr. Geo. H. B. Macleod, Regius Prof. Surg. Univ. of Glasgow, who "advocates

a modification of the usual practice in amputation through joints, which consists in leaving, in every case in which it can be done, the proximal bone with its incrusting cartilage untouched in the stump." The advantages he claims for this are that "exarticulation is quicker, easier, requires simpler instruments, and is attended with far less bleeding (from our having to deal, as a rule, with the main arterial trunk), than amputation in continuity. By not touching the cartilage we can keep further from the trunk, have a longer stump, and not expose the very vascular and, hence, very absorbent end of the long proximal bone. There are here very great and important benefits which need not be enlarged upon. The risks of septicæmia and osteo-myelit is ae reduced to the lowest attainable point as the bone (the chief agent of absorption in stumps) remains sealed. Operations thus performed are attended with much less shock, the integuments preserved are, as a rule, those best fitted for withstanding pressure, there is vastly less risk of injury to the flaps and bloodvessels and nerves by the action of the unsawn bone acting on them, and hence we need not fear protrusion or pain subsequently; we are less apt to be troubled by the retraction of the muscles as their close adhesion to the bone down to its end is not weakened; the power of sustaining the pressure of the apparatus is much earlier acquired, and the point of support is broader and better fitted for pressure than when the bone has been divided. If to this we add that the anastomosis of the bloodvessels in such flaps is very quickly established from the large supply of twigs on the level with joints, that we have no bleeding from the bone to deal with or dread, and that a false limb can with perfect success be fitted so as to retain the joint motion with a stump of the natural length, all the leading advantages of the mode of operating dealt with will have been stated, and it must be allowed that such advantages are neither few nor inconsiderable. Of course, we cannot amputate through a joint the seat of malignant disease; but it is in secondary amputations for accident that the most marked good is obtained, and it is in such cases that the great dangers of septicæmia and osteo-myelitis are apt to arise. It may be further added that

the redundant size of the articulating head of the bone, which is in some cases left in the stump, in time disappears and it becomes beautifully rounded and well adapted for the end of a stump."[1]

Prof. Velpeau says: "The advantages of disarticulation are, that it is more prompt and easy than amputation in the body of the limbs; that it does not require the section of the bones, is more favorable to immediate union, and enables us to preserve a longer stump. Its disadvantages, at least in a large number of cases, are, that it lays bare extensive osseous or cartilaginous surfaces; that it obliges us to carry the instrument upon the thickest parts of the bones, which are least abundantly supplied with soft parts, and to make use frequently of tendinous or synovial tissues for closing the wound; and that it also makes a solution of continuity, somewhat irregular; but it is not true, other things being equal, that it endangers, more than amputation in the continuity, as had been for a long period thought, nervous symptoms, tetanus, abscesses, purulent collections, and symptoms of general reaction. It requires but few instruments, and no necessity of such complicated dressings as are demanded in amputation in the continuity. A knife or simple bistoury is generally all that is needed to perform every step of the operation. So also have we less to fear from the conicity of the stump, the projection of the bones, or the retraction of the muscles. As the soft parts are but slightly displaced, the adhesion of the flaps is obtained with facility, and the inflammation proceeds no farther than is requisite to secure immediate union. The division acting only on the skin, the cellular and fibrous tissues, and some of the attachments of the muscles, inflammation, abscesses, and constitutional reaction, are, in general, but little to be apprehended. Though very large in appearance, the wound has in reality but very little extent, because the cartilaginous surfaces at the bottom of it, being deprived of all sensibility and wholly inert, take no part in the process of suppuration or inflammation. M. Kerst, Professor in the Military Hospital of

[1] Am. Jour. Med. Sci., vol. lxix. (1875), p. 558.

Instruction at Utrecht, prefers, as a general rule, disarticulation to amputation in the continuity, because from the last we have to apprehend traumatic fever of a pernicious (pernicieuse) and intermittent character, together with inflammation of the veins in the sawed bone. The dread which prevailed among surgeons of the last century, of wounding the inter-articular (diarthrodiaux) cartilages, exposing them to the air, and touching them with the instrument, is at the present day entirely dispelled."[1]

Having presented the essential views of surgeons in reference to the advantages and disadvantages arising from disarticulation, it now remains for us to examine the pathological changes which take place in the cartilages that remain behind after the performance of the operation. This is especially necessary since it is no longer customary to remove them. Velpeau says on this subject: "If the agglutination is not immediate, the cartilaginous surface, acted upon by the cellular granulations which are formed upon the bone, soon detaches itself, sometimes in fragments, sometimes in large pieces, (plaques,) at other times in the form of a shell, (coque,) and soon completely exfoliates, leaving exposed a vermilion-colored wound, which afterwards cicatrizes with great facility. In the contrary case it does not perceptibly change its appearance, it only loses its polish and becomes rugose, (rugueuse;) but a molecular action soon developes itself, erodes (miner,) and insensibly dissolves it, until it has temporarily disappeared. Constituting the true epiderma of the bones, and consisting of a simple anhiste (anhiste) tissue, it cannot, with the attributes that belong to it, exist any longer than while the articular movements are preserved. As soon as the living tissues rest permanently upon it (la touchent à demeure), the vitality of the bones, properly so called, begins to act upon it and to destroy it, by creating the cellulo-fibrous deposition, (couche,) which is the base of every sound cicatrix, unless in its actual state of cartilage (véritable épichondre,) it becomes agglutinated to the soft tissues, by becoming, as M. Champion thinks, organized and blended with them. By one mode or the

[1] Operative Surgery, ed. by Mott, vol. ii. p. 488.

other, the tendons, aponeuroses, nerves, and vessels, ultimately become firmly adherent upon the extremity of the stump, so much so that the patient is enabled to move it with as much facility after the cure as before the operation."[1]

A portion of the arguments urged in favor of amputations through the joints in preference to the performance of the operation in the continuity of the bones are certainly entitled to a careful consideration. It was claimed that the dangers in cases of disarticulation arising from septicæmia and other infectious diseases were reduced to the minimum, and this claim remained undisputed prior to the introduction of Lister's antiseptic wound treatment; but the proper application of this system affords even greater protection against septic infection than had been previously thought possible. Amputations in continuity, as well as those in contiguity, are now performed without the least fear of septic complications. Surgeons are no longer in mortal dread of the retraction of the muscles of the stump or the protrusion and exfoliation of the sawed bone. These morbid conditions, as well as the sugar-loaf or conical stump, commonly arise from some form of septic disease, which usually has its nidus in the amputation wound. The claim that an amputation through a joint is followed by less shock, less hemorrhage, and complete absence of all danger from the employment of a saw, are subjects of minor importance. It must however be admitted that there is no danger of hemorrhage from the bone, or that through the bungling use of the saw an injury may be done to the nerves in the flaps or any other portions of the soft parts; but it should also be remembered that there is a liberal distribution of arteries about the large articulations, and this fact makes it necessary to apply a large number of ligatures, whilst there is a proportionate increase of danger from secondary hemorrhage. It has been furthermore asserted that the amputation in contiguity may be performed with more ease, greater rapidity, and with fewer instruments; and although we are compelled to admit that fewer instruments are required, we are

[1] Ibid. p. 488.

nevertheless inclined to deny that the operation is performed more rapidly or with greater ease. Having now examined some of the advantages claimed for amputation in contiguity compared with the operation in the continuity of the long bones we will now mention some of the disadvantages in the same connection and then enter upon our final conclusions. Prior to attempting the performance of an amputation in contiguity the surgeon ought always to fix the exact point at which he will enter the joint, and this is determined by certain well-known anatomical landmarks which serve as guides. Having found these, and knowing their relation to the joint, or to that particular part which the surgeon desires to enter, there is no longer much trouble in completing the operation. Surgeons are influenced by the same principles in selecting the method of operative procedure in case of an amputation in contiguity as in an operation of continuity. This question will be fully discussed hereafter in connection with the consideration of the various methods, such as circular, flap, etc. The removal of large capsules is unquestionably advantageous when they are so situated in the flaps as to delay the healing process. The tendons and nerves found in the flaps of amputation wounds ought to be drawn forward and cut short, that their presence may not interfere with immediate union, or give rise to pain in the cicatrix. The surgeon is likely to find some trouble in neatly approximating the flaps to every part of the articular surfaces in certain joints; but observation has taught us the incorrectness of the opinion which was formerly held by Beclard and others who claimed that after a disarticulation the smooth surface of cartilage does not unite with the flaps unless an inflammation has been first excited.

Velpeau informs us, however, that: "The fistulas which sometimes follow amputations at the joints, are owing either to some point of the cartilaginous surface which has not exfoliated or become adherent to the flap of the soft parts, continue to exude synovia; or to one or more of the tendinous sheaths which have not closed, furnishing fluids of the same nature in quantities sufficient to become an impediment to the agglutination of the tissues. These difficulties are in general very easily overcome,

and almost always without any serious consequences, by means of compression, stimulating injections, cauterization, &c. Moreover, amputations in the continuity are by no means absolutely exempt from such accidents. If, therefore, in amputating below the articulation we can remove all the disease, and at the same time preserve a sufficiency of tissues to close the wound, amputation in the continuity ought to have the preference; on the contrary it is better to amputate at the joint than to go above it. On the other hand, if in amputating at the articulation we should incur the risk of removing all the disease, we should renounce it and carry the instrument higher up. When in amputating in the continuity we are obliged to make the section of the bones too near the great synovial cavities, disarticulation is the preferable course. The danger of purulent arthritis is then too imminent not to justify the immediate sacrifice of the joint. . . . . In conclusion, the extirpation of the limbs is not more dangerous than their amputation, properly so called, and it is the extent of the disease and the functions of the organ to be removed, which are to influence the surgeon in his preference for one of these methods over the other, in the particular cases that present."[1]

We will not enter on the consideration of the *various methods of amputating the extremities*. The history of this subject has already been presented; but there still remains for our investigation the operative procedures and the peculiar advantages and disadvantages of the various methods. Let us here add that each method of operative procedure may possess, under certain circumstances, a marked advantage over some or all of the others; but all arguments in favor of a particular method of operating should always be based on physiological, anatomical, or pathological elements. There are certain cardinal points which ought never to be forgotten by the surgeon while either contemplating or performing amputation; and here we may mention that the operation should be so performed as to give the patient the best chance of life, the most serviceable stump,

[1] Ibid. p. 489.

the least suffering, and the most speedy recovery. Unquestionably, the full consummation of these objects will depend much more on the skill and care exercised in the after-treatment than on the operation itself; but if the first part of the work is bungled, the second part then becomes more difficult. Every surgeon is perfectly aware that he may be annoyed in his after-treatment by flaps which are either too large or too small, as well as by many other mishaps which belong to the operation. Already much has been written on the general superiorty of the circular operation over the flap, and *vice versa*, but no unanimity on this question has yet been reached, and the language of Fergusson on this point appears remarkably appropriate. He says: "I have seen as good stumps from the circular operation as from the flap; I have seen as bad from the flap as from the circular; and I have long been convinced that a fault, whenever it has appeared, has in reality been more in the manner than in the method of operation."[1]

Frederick James Gant, F.R.C.S., says on this subject: "The *relative merits* of these two modes of amputation have been much discussed; and some surgeons have practised almost exclusively the one and some the other operation. Mr. Liston advocated flap amputation, and Sir W. Fergusson seemed to prefer it, although fully acknowledging the good results of circular amputation in the hands of many excellent surgeons. . . . Prof. Spence, who has paid great attention to the subject of amputation, gives the preference to the flap operation, as compared with the circular method, subject to certain modifications of the former method."[2]

Erichsen remarks that: "During the late Franco-Prussian war, the circular was the method almost universally adopted by the German surgeons; the advantage they claim for it being that much less care is required in the after-treatment than in the flap method, as the covering to the bones, containing no muscle, is less liable to be displaced, and the patients will con-

[1] London Lancet, July 8, 1865, p. 29.
[2] Science and Practice of Surgery, 2d ed., vol. ii, p. 95.

sequently bear transportation from the field hospitals at an earlier period, a matter of no small importance in military surgery; there is also said to be less liability to sloughing than when the operation is performed by long skin flaps. In some cases of malignant disease, also, when it is desirable not to approach too near to the diseased portion of the limb, the circular may be found a safer operation than the flap method, as far as the ultimate condition of the patient is concerned, in lessening the liability to recurrence. . . . . The rectangular method undoubtedly possesses one very great advantage over the circular or ordinary flap, in giving a soft and loose covering to the ends of the bones, admitting of direct bearing upon them; especially advantageous after the amputation of the thigh or leg, when direct pressure can scarcely be dispensed with, and when a solid, firm stump it is of very essential service to the patient."[1]

Prof. Frank Hastings Hamilton says: "Without entering into a discussion of the relative merits of the two operations, I will simply state my belief that both have special and appropriate applications, depending upon the point at which the amputation is to be made, the character of the injury, the general condition of the patient, and the circumstances which are to attend the subsequent treatment. . . . When the character of the injury is to decide the preference, the surgeon alone can determine the choice after he has examined the limb, and ascertained what resources the lacerated tissues offer for a proper covering to the stump. In relation to the condition ot the patient, it is my opinion that when, in consequence of long-continued suppuration, exhausting hemorrhages, or any other cause, the system is greatly enfeebled, the circular method ought generally to be chosen; and for the reason that the tegumentary coverings of a circular amputation are less liable to gangrene and suppuration, and to become depots of foul secretions by which the system may be contaminated, than are the large fleshy masses formed in the flap operations. There is

[1] Science and Art of Surgery, 7th Amer. ed., vol. i. p. 62.

one other point in this connection, relating chiefly to military surgery, to which it seems necessary to call attention. Whenever a patient is to be transported immediately or soon after the operation a long distance, preference ought always to be given to the circular amputation, at least in the case of all large limbs, and especially in the case of the lower extremities. The heavy flaps attached to the end of the limb, disturbed by incessant motion, are exceedingly apt to loosen and become gangrenous."[1]

Prof. Samuel D. Gross expresses his preference in the following positive manner: "The one which I prefer is that by the flap, though a most excellent stump may also be made by the circular operation. The rectangular method is well worthy of attention, as the arrangement of the long flap not only thoroughly protects the bone, but, what is of great consequence, admits of ready drainage. The oval operation is admirably adapted to amputations at the joints and to resection of the bones. My reasons for preferring the flap to the circular operation are, first, because it is more simple and easy of execution; secondly, because it makes, as a general rule, a much better covering for the bone; and, lastly, because the patient experiences much greater comfort in wearing an artificial substitute. During the sitting of the commission appointed by Surgeon-General Hammond, to report on the subject of artificial limbs, convened at New York in 1862, upwards of a dozen manufacturers, then present, unanimously assured me that stumps made by the circular operation are, as a general rule, in every respect inferior to such as are made by the flap method; that it is much more difficult to fit them with an artificial substitute; and that they are a great deal more liable to become chafed, irritated, and ulcerated. The results of my own observations are precisely of the same character. I have been at much pains, by visiting some of our military hospitals, to inform myself personally of the comparative merits of the two operations, and, from all that I have witnessed, the preponderance is vastly in favor of the flap

[1] Principles and Practice of Surgery, p. 346.

method. Dr. R. J. Levis, surgeon in charge of the government hospital in this city for the cure of bad stumps, bears similar testimony."[1]

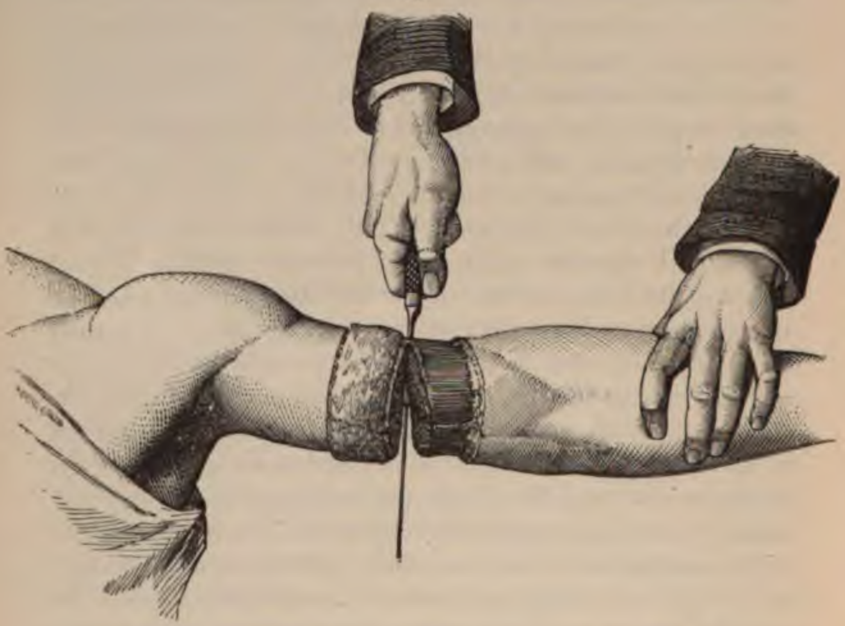
Velpeau concludes his remarks on the comparative value of the circular and flap methods in the following words: "In conclusion, too much importance, as I think, has been generally accorded to the flap operation. The wound which it causes has necessarily a much greater extent of surface than if it was circular. The muscles which this mode deems it so important to preserve, are exposed to various accidents. If they should be attacked with inflammation, they suppurate most abundantly, absorb the fluid like a sponge, and favor to a remarkable degree purulent infection and phlebitis. On the other hand, they scarcely ever become adherent (refixent) to the apex of the stump in the centre of the cicatrix. By whatever mode we may proceed, it is the skin which finally becomes united to the cut surface of the bone, and the side of the flaps through means of the retraction of the angles of the wound, favors to a greater degree than any other method the protrusion of the bones."[2]

Prof. Pitha prefers the circular operation whenever the circumstances of the case will permit it. His reasons mentioned for this preference are that this method makes relatively the smallest wound and the vessels and nerves are cut transversely instead of obliquely, as in the flap operation. We might continue to cite surgical authorities and their preferences *ad infinitum*; but enough has already been done in this direction to show the complete want of unanimity among those who are by their education and experience the most competent judges on this subject; nevertheless we have succeeded by this process in bringing to light the various conditions on which their preferences and antipathies are based. The value of this knowledge will become more apparent to us when we enter on a description of special amputations in the succeeding chapters of this work. We have already observed that all amputations, whether performed in the

[1] System of Surgery, 4th ed., vol. i. p. 508.
[2] Operative Surgery, ed. by Mott, vol. ii. p. 484.

contiguity or continuity of the bones of the extremities are regarded either as circular or flap operations, or modifications of these methods. We have thus far presumed on the reader's knowledge of these operations in the investigation of their relative value, but before proceeding further we will direct attention to the following wood-cuts, Figs. 6 and 7, which may be found

Fig. 6.

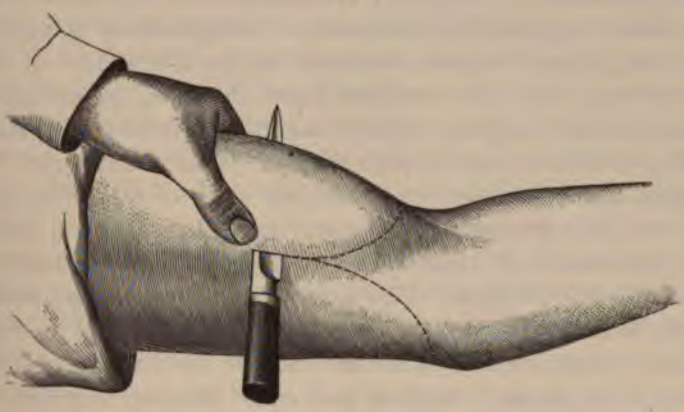


useful for our present purpose even without the description of these operations which will appear in a subsequent chapter.

It will be observed that the most essential difference between the circular and flap operations consists in the fact, that, in the former case the flap is composed of integument and subcutaneous cellular tissues; and in the latter the flaps include also a muscular portion. Is the presence of this muscular portion in the flaps advantageous? The answer to this question must be made conditional, and must depend greatly on the condition of the parts, the disease or traumatism for which the amputation is performed,

the point at which the operation is made, and also the after-treatment. Let us here mention the objects which every surgeon ought always endeavor to obtain in each amputation, that the application of our means may have a special reference to

Fig. 7.



the accomplishment of the ends sought. The first object of the surgeon is to give the patient the best chance of life which is possible under the circumstances, and the second consideration demands the most serviceable stump; the third, the least amount of suffering, and the fourth the speediest recovery. The preservation of life being the primary motor actuating a surgeon in the choice of a method of amputating suggests here an inquiry into the dangers attending the performance of the circular operation as compared with the flap method. Surgical authorities generally admit that flap amputations are more frequently followed by secondary hemorrhage, septic infection, inflammation, gangrene, and sloughing of the flaps, than those performed by the circular method. The preponderance of the evidence being in favor of this assertion, we are therefore somewhat reluctantly compelled to accept it; and since it appears that the performance of the flap operation is more dangerous to the life of our patients let us determine, if possible, if there is any rational explanation of the same. The increased frequency of secondary

hemorrhage after amputations performed according to the flap method is explained by the fact that in the first instance the ligation of the arteries is rendered more difficult on account of the oblique character of the incision, and consequently this part of the operation is not usually so well performed as when the circular method is employed; secondly, it naturally follows that the more frequent the occurrence of inflammation, gangrene, and sloughing, the more frequent will be the attacks of this hemorrhage. If it is true that septic infection, inflammation, gangrene, and sloughing more frequently follow the performance of flap operations than circular, then we ought to investigate the subject and determine, if possible, the cause of this difference. Are the same precautions commonly taken by operators, during the performance of amputations by these different methods, to prevent septic infection? The answer to this question must certainly be in the affirmative, and therefore it is just to presume that the operation itself is less favorable to life than the circular. There is no reason to suppose that septic infection originates in these cases very frequently as a primary affection, but, on the contrary, the fact that inflammation, gangrene, and sloughing have been more frequently observed to follow the performance of flap than circular operations renders it very probable that this diseased condition arises generally in connection with the above-mentioned diseases. The more frequent existence of these diseases after the performance of flap amputations than what prevails after the performance of the operation by the circular method suggests to our mind that their origin may be due to a less favorable condition of the circulation of the blood, and a consequent disturbed or diminished nutrition of the parts. The blood supply of the skin in every part of the extremities is abundant and unquestionably the tissues entering into its formation are possessed of a much higher vitality than those of the muscles, their sheaths and tendons. "The arteries which supply the skin divide into numerous branches in the subcutaneous tissue; they then pass through the areolæ of the corium, and divide into a dense capillary plexus, which supplies the sudoriferous and sebaceous glands and the hair follicles, terminating

in the superficial layers of the corium, by forming a capillar network, from which numerous fine branches ascend to the papillæ."[1]

Prof. S. Stricker, of Vienna, refers to the bloodvessels of the skin in the following language: "The vascular trunks which ascend obliquely through the subcutaneous tissue, and give off branches there to the fatty tissue, sweat-glands, etc., anastomose freely in the deeper parts of the corium, forming a network from which twigs run in a slanting direction to the outer portion."[2] The cutaneous arteries of the extremity are commonly given off from the main arterial trunk, less frequently from its branches in its passage through the subcutaneous cellular tissue, at those points in its course where the vessel is situated externally to the muscles. Furthermore these branches are solely cutaneous, and, it may be further stated, as a general rule, that they do not anastomose with the arteries distributed to muscles. The chief cutaneous arteries of the upper and middle thirds of the thigh arise directly from the femoral artery in Scarpa's triangle, pass downwards in the subcutaneous cellular tissue, and are distributed to the integument over those parts. The lower third of the thigh and the upper portion of the leg are abundantly supplied with cutaneous branches which arise from the popliteal artery in the popliteal space. These arteries are so numerous and anastomose so freely in the integument about the knee-joint as to form a complete network, which extends above it about five or six inches and as far below. Besides these anastomosing arteries about the joint there are cutaneous branches which descend on each side, and in the middle of the limb, between the gastrocnemius and integument, that arise separately from the popliteal artery, or from some of its branches and supply the integument of the calf. The fact that arteries are more numerous and anastomose more frequently in the limbs about the joints than elsewhere, has long since been observed and

[1] Gray's Anatomy, a new Amer., from the fifth enlarged Eng. ed., p. 88.

[2] Manual of Histology, New York, 1872, p. 546.

noted by anatomists, being equally as true of the muscular as of the cutaneous. The veins of both the lower and upper extremities are subdivided into two sets, superficial and deep. The superficial veins are placed beneath the integument, in the subcutaneous cellular tissue, or what is frequently called in this connection the superficial fascia. The superficial veins of the lower extremity are the internal or long saphenous, and the external or short saphenous. These veins receive in their course blood from the various cutaneous branches throughout the whole length of the extremity. The long saphenous vein passes through the saphenous opening in the fascia lata, and terminates in the femoral vein about one inch and a half below Poupart's ligament. The short saphenous vein passes directly upwards, perforates the deep fascia in the lower part of the popliteal space, and terminates in popliteal vein between the heads of the gastrocnemius muscle. This examination of the arterial and venous distribution in the extremities *justifies the conclusion* in our opinion, that the *cutaneous* circulation in these parts is *essentially independent of the muscular*. We are greatly indebted to Dr. Hilton for having called our attention to the fact that the distribution of the arteries, like the nerves, is made with *designed accuracy*, and possesses a peculiar adaptation to the structure and functions of the parts. In illustration of this opinion he cites the following: "Take, for instance, the cœliac artery, which is distributed to the organs of digestion, and nothing else; it supplies the liver, stomach, pancreas, spleen, and part of the duodenum, that is all it does. As these are all organs connected with the process of digestion, the cœliac artery might well be called the 'digestive artery.' Take another illustration, the os hyoides, placed between the larynx and the pharynx, is functionally and structurally associated with both. Does not anatomy tell us that the os hyoides receives a hyoidal branch from the superior laryngeal artery, and a hyoidal branch from the lingual artery on each side? Is not the os hyoides connected with the functional and structural integrity of both the larynx and the tongue, intimating

the reason of the double source of arterial blood for its growth and nutrition.[1]

Numerous other examples are cited by the same author, and all illustrate the same general law. It may now be safely asserted that the circulation of the blood in the skin, *which is essentially independent of that in the muscles and deep-seated tissues, is no exception to the general rule, but, on the contrary, it is in perfect harmony with the examples pointed out by Dr. Hilton, and bears the same relation to the structure and the functions of the parts.* We are now prepared to make a practical application of these facts to amputations in the extremities, and have secured an anatomical basis in the independent cutaneous circulation of the blood, which will assist us in explaining the greater frequency of inflammation, gangrene, and sloughing after the performance of the musculo-cutaneous flap amputation, than what follows the cutaneous circular operation. The first point to which we now desire to call attention in connection with these operations, is the fact, that the circulation of the blood in the skin being independent of that in the muscles, precludes the possibility of aiding the nutrition of the integument by the retention of muscles in the flaps. Furthermore, we think it may be fairly claimed that the single circular cut through the integument interferes less with the cutaneous circulation than either a single or double crescent-shaped incision. We have now shown that the retention of a muscular portion in the flaps cannot diminish the frequency of inflammation, gangrene, or sloughing; but it is equally important to determine whether its presence may not give rise under certain circumstances to these morbid conditions? Unquestionably its retention may give rise to these morbid conditions after certain traumatic injuries. An extravasation of blood within the muscular portion, or the laceration of its tissues are conditions fraught with dangers to the well-being of the patient; and their existence is not inconsistent with a healthy state of the integument. Either of these conditions may give rise to inflammation and its concomitant evils. Œdema of the

[1] Rest and Pain, New York, 1879, p. 168.

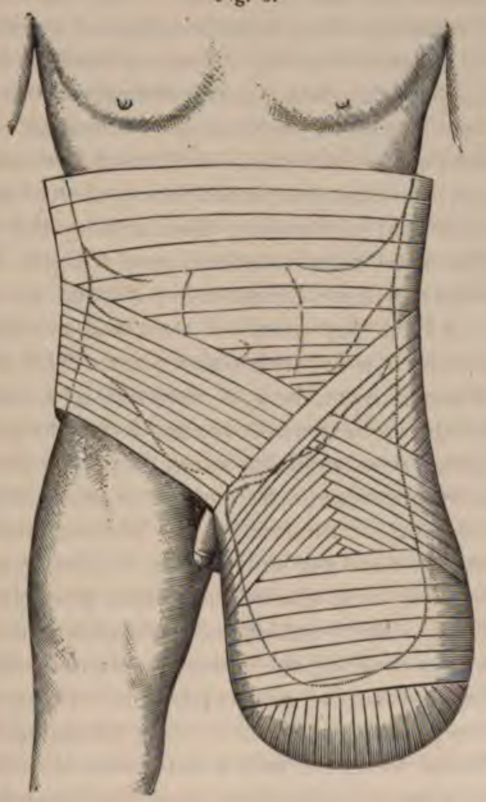
muscular portion causes it to press on the integument, and this pressure interferes with its nutrition, whilst the putrefaction of an albuminoid substance may give rise to septic infection, etc. The performance of the flap operation is often followed by the protrusion of muscle beyond the integument, and Dr. LeGros Clark has called attention to the importance of this subject in the following language: "If muscle be included in the flap, there must be security for the skin extending well beyond it; and it is well to remember that in amputations for recent injuries, the retraction of the skin is much greater than in amputation for long-standing disease. Practically this is the case, though the explanation probably is that the healthy, well-exercised muscle contracts much more during incision than that which has been long diseased; and that, therefore, after division its subsequent relaxation leaves it, relatively, much longer than the skin. Attention to this hint will obviate much disappointment, especially in flap operations."[1]

In addition to the above remarks, we desire to call attention to the fact that the readiness with which the muscles protrude beyond the integument conveys an accurate idea of the very slight connection existing between the skin and muscles. The inconvenience occasioned by this protrusion may be either avoided or remedied. The avoidance may be accomplished by first cutting the skin flaps, and raising them to the requisite height, after which the muscles may be incised so as to give them the proper length; but where the flaps have been formed by transfixion, or otherwise, and the muscles being found to protrude beyond the integument, the remedy under such circumstances consists in the removal of the redundant tissues with the knife. Mr. Erichsen, Prof. Frank H. Hamilton, and many other writers on military surgery have expressed their preference for the circular operation, rather than the flap method, in all cases where the parties operated on are liable to be transported or deprived of the ordinary amount of surgical care, change of dressing, etc. This recommendation is based on the fact that

[1] Outlines of Surgery, 2d ed., p. 189.

the constant jolting in the transportation is more liable to displace the flaps which contain a muscular portion on account of their increased weight. Here let us add that this objection may be easily overcome by the application of Guérin's cotton wadding dressing, which not only prevents all motion of the flaps during transportation; but it maintains at the same time uniform pressure, which secures the general approximation of

Fig. 8.



every portion of the cut surfaces, thus materially aiding in obtaining union by first intention. Furthermore this dressing possesses an unquestionable antiseptic value, and having been once properly applied need not be changed for many days or

even weeks; whilst its elasticity affords a patient a very high degree of comfort even in transportation in an ambulance over a rough corduroy road. A very good idea of this dressing, and a fair opportunity to estimate its value, may be gained from an inspection of the preceding illustration, Fig. 8.

The flap operation is decidedly preferable in one respect to the circular, as it enables the operator to close the amputation wound without folds or wrinkles; nor is this to be regarded merely as a matter of neatness. The wound must be accurately closed, and remain in this condition several days in order to secure union by first intention. It was probably with the intention of remedying this defect in the ordinary circular operation that Mr. Syme in 1846 introduced a modification which is described as follows: "It consists in forming *two semilunar* incisions through *the integument*, which are dissected and retracted upwards for at least two inches; then cutting the muscle on a level with the retracted skin obliquely up towards the bone, the muscle on the posterior aspect being divided at a somewhat lower line. All the soft parts are then well retracted, and the bone cleared and sawn at its highest point. This is sometimes known as the mixed 'method of amputation,' a combination of the flap with the circular methods; and it may be performed by means of lateral, or of antero-posterior flaps. It is equally well adapted for amputations in the upper or lower limbs, and especially in the leg or the forearm."[1] The accurate closure of the amputation-wound not only assists in procuring union by first intention, but it is also an important prophylaxis against septic infection. The wrinkles and folds observed on the surface of the flaps covering the stump generally correspond more or less accurately to the pockets within. These pockets are commonly very quickly filled with an albuminoid substance, which if allowed to remain only a few hours, after having been exposed to an impure atmosphere, must rapidly undergo decomposition. A desire to avoid the many evils arising from the decomposition of these fluids, which are so favorably situated

[1] Gant's Science and Practice of Surgery, vol. ii. p. 95.

for putrefaction and absorption, prompted O'Halloran to leave the amputation-wound open after the performance of the operation until its whole surface was covered with granulations. His practice was followed by others, notwithstanding the many objections which pertain to it, and it still continues to be occasionally employed. Drainage tubes, which are now so extensively employed in cases of amputations, were first used by Chassaignac for the purpose of conducting away the wound secretions, and thus avoiding the evils arising from them; but even the successful use of these requires neatness in the approximation of the flaps. Furthermore, we are strongly inclined to think that every surgeon who has employed drainage tubes, both in the circular and the flap operations, will feel constrained to admit that their use was, at least, more convenient in the latter cases, if not more satisfactory, than in the former.

There is another point which has been strongly urged by the advocates of the flap amputation, and which therefore demands our consideration. They claim that *this operation* generally makes a better covering for the bone, and that the patient commonly wears an artificial limb with more comfort. The value of this claim must certainly depend on its being satisfactorily proven. Has this been accomplished? This query must be answered negatively, although some surgeons are willing to admit that the stump made by the flap operation presents a more comely appearance during the first two years than that which commonly follows the performance of the circular operation, whilst many others firmly believe that both its beauty and utility depend principally on the after-treatment. The stump made by the flap amputation loses much of its smoothness, plumpness, and beauty during the first few months, the muscular portion of the flaps atrophy, and the integument becomes loose and wrinkled, whilst the changes which follow the performance of the circular are very slight. The plea that the flap amputation is simpler and easier of execution is scarcely entitled to a consideration, since the surgeon ought always to consult the good of his patient instead of his own personal ease or convenience. Furthermore, the circular operation is very easily exe-

cuted, and we are much inclined to think that the comparative ease and rapidity with which either is performed depends greatly on the preference and resultant habits of the operator. It is scarcely necessary to add that the sugar-loaf or conical stump, which in ancient times arose from the unskilful performance of amputation, ought now never to be seen, except as the result of inflammation or sloughing, and we have already shown the extent to which these conditions may be dependent on the method of operative procedure. Our investigation of the comparative merits of the circular and flap methods has been performed with unusual care, because we regard all other amputations as modifications of these operations, and we now express the practical conclusions: 1. The circular amputation (cutaneous flap) is less liable to be followed by septic infection, inflammation, gangrene, and sloughing, and therefore ought to be preferred in all cases where the surgeon is entirely free to choose, if there exists any special danger of these complications which cannot be successfully counteracted by other means. 2. The flap amputation (musculo-cutaneous) supplies those conditions most favorable to immediate union, especially in the thigh and arm, and therefore it ought to be preferred unless this advantage be counterbalanced by the danger arising from complications peculiar to this method of operation. 3. The success of an amputation does not depend so much on the method of operative procedure as on the care exercised in the performance of the operation and the after-treatment; and while the advantages and disadvantages of each method should be thoroughly understood by every surgeon, who is consequently prepared to make an intelligent choice of an operation with especial reference to the character and locality of the lesion, as well as all the other circumstances pertaining to the case. It occasionally happens, owing to the character or locality of the injury, that a surgeon finds himself unable to follow any particular method in his operation, and in fact the covering over the end of the bone may be a complete patchwork, while nevertheless the result is commonly favorable, where due attention has been given to age and other complications. Many other so-called methods, but

really modifications of the circular or flap operation, are employed by operators, and are often found convenient, if not positively advantageous. Furthermore, some of the so-called methods are really modifications of both the former and latter. Alanson's method, which he employed so successfully during the latter part of the eighteenth century, resembled in its external appearance the circular operation, whilst the character of the flap (musculo-cutaneous) was identical in this respect with that first proposed by Lowdham, but the wound arising from the performance of the operation was cone-shaped. The oval method (musculo-cutaneous) which was introduced to the profession in the year 1827 by M. Scoutetten must be regarded as a modification of the common flap operation. The elliptic method was introduced by Prof. Söupart, and consists in the formation of a flap whose rounded and convex border is received into a concave wound formed on the opposite side of the limb. This is a cutaneous flap operation, and is commonly regarded as a modification of the circular method. Mr. Teale, of Leeds, introduced a modification of the ordinary flap amputation which has been designated the rectangular method. This operation is performed with two flaps, one long and the other short. Numerous other modifications of the circular and flap amputations have been employed and will be described in the subsequent chapters of this work, while we are especially engaged with the consideration of the various operative procedures. The surgeon in private practice prior to commencing the performance of an amputation ought always to take careful survey of the patient's surroundings. The motive for this action is twofold: first, to ascertain the changes, in or about the room which may be required to facilitate the performance of the operation; and secondly, what can be done which will give the patient a better chance for recovery.

We shall not attempt under either of their heads to call the surgeon's attention to all the details which ought to be arranged, but shall content ourselves by merely mentioning the more important requisites. The importance of light during the performance of an amputation cannot be well overrated, and the

questions pertaining to it naturally divide themselves into quality, quantity, and place. Sunlight is to be preferred, but cannot always be had, and in its absence artificial light may be employed. Let the surgeon in the selection of artificial light choose the first at hand, and be always sure to have enough. Furthermore, he ought to be prepared to direct the light to any point where it may be required by the aid of reflectors, and nothing answers this purpose better than mirrors. The room in which the operation is to take place should be sufficiently large not to inconvenience the surgeon in the performance of his work. An operating table may be extemporized with the tables at hand, or the operation may be performed while the patient reclines on a lounge or bed. The future welfare of the patient demands that the surgeon, even before he commences the performance of an operation should carefully weigh the hygienic surroundings, and everything else which may add to the patient's safety and comfort. Let not even the position of the patient in bed, the situation of the bed, or the other articles of furniture in the room be thought unworthy of the surgeon's care. Attention to these little things frequently increases the patient's chances of life by facilitating nursing and adding to his present comfort.

We now enter on the consideration of the SELECTION AND ADMINISTRATION OF AN ANÆSTHETIC. The first question which arises in connection with this subject is, On what basis shall this choice be made; shall it be the safety of the patient, the agreeability of the anæsthetic, or the time required to produce anæsthesia? These questions must be considered separately, and conjointly; and before entering on their consideration we will announce the fact that we intend to limit ourselves to three anæsthetics, viz., chloroform, ether, and bromide of ethyl. It can no longer be doubted that the use of chloroform, as an anæsthetic in civil practice, is attended with a considerable mortality, although in military service there are comparatively few deaths caused by this agent. Does this mortality arise from the improper administration of the drug, its impurities, or its lethal properties? It may not be possible to demonstrate the chief source of danger in the use of chloroform as an anæsthetic agent;

but there is certainly enough known on this subject to justify the assertion that ignorance and carelessness have already caused many deaths with it. Dr. R. J. Levis has recently called our attention to an illustrative case, and here it may be added that similar occurrences in the practice of surgery are by no means rare. He says: "I have witnessed an ignorant and heedless assistant resting his elbows on the chest of a patient whose labored respiration and livid turgid face showed threatening asphyxia, while the administrator gazed abstractedly at a surgical procedure taking place at the groin."[1] It is probably safe to attribute more than one-half of all the deaths which occur during the administration of chloroform to these causes. The chief impurities of chloroform are not dangerous to life, and are easily recognized by the chemist. Among the most injurious may be mentioned the chlorinated pyrogenous oils and hydrochloric acid.

Dr. Snow says on this subject: "I am not aware of serious consequences having arisen anywhere from the impurities or adulterations of chloroform. A case occurred in the London Hospital, where a cough and a feeling of suffocation were caused by hydrochloric acid with which the chloroform was contaminated, but the inhalation was discontinued, and no ill consequences resulted."[2] It may be finally questioned whether the impurities of the drug have produced death in a single instance, although they have occasionally caused cough, headache, and other inconveniences; but it is to be regretted that we cannot say as much in favor of the chloroform. It is unquestionably true that chloroform, like all other narcotics, is capable of producing death when taken in an overdose, and here lies the essential danger connected with the administration of the drug for surgical operations. An overdose of chloroform is generally supposed to destroy life by causing paralysis of the heart, and consequently it becomes important to determine whether it is possible to avoid these fatal doses. Numerous

[1] New York Medical Record, vol. xvii. p. 346.
[2] On Chloroform and other Anæsthetics, p. 32.

careful experiments have been made to determine these facts, and Dr. Snow says: "I find that if I put twelve minims into a bladder containing a little air, and breathe it over and over again, in the manner of taking nitrous oxide, it suffices to remove consciousness, producing the second degree of its effects. To induce the third degree of narcotism, or the condition in which surgical operations are usually commenced, would require that about eighteen minims should be absorbed by an adult of average size and health, according to the above method of calculation; and to induce the deep state of insensibility, which I have termed the fourth degree of narcotism, would require twenty-four minims; whilst to arrest the function of respiration would require that about thirty-six minims should be absorbed."[1] Dr. Snow further reports: "That eighteen minims of chloroform is the average quantity in the system of an adult, when sufficiently insensible for a surgical operation, and that this amount might be absorbed by the use of thirty-six minims, allowing one-half of the quantity breathed to be exhaled again, without being absorbed; but thirty-six minims of chloroform make only 37.5 cubic inches of vapor, which, at the temperature of 60° Fahr., may exist in combination with 257 cubic inches of air, making it expand to not quite 300 cubic inches; the whole of which might be breathed in twelve ordinary inspirations of 25 cubic inches each. If the inhalation of vapor of this strength were continued till insensibility was induced, the lungs would still contain a great quantity of unabsorbed vapor. The amount of air usually present in the lungs is about 250 cubic inches, and if saturated with chloroform at the temperature of 60°, it would contain the vapor of thirty minims. About half of this might be absorbed, the remaining half passing off in the expired air; but the addition of fifteen minims to the eighteen minims already absorbed would almost double the quantity of chloroform in the system, and bring the patient necessarily to the brink of death."[2]

The clear statement of these facts which are based on experi-

[1] Ibid. p. 74.

[2] Ibid. p. 107.

mental knowledge, brings lucidly before us the unavoidable danger of the inhalation of the vapor of chloroform, as employed in surgery. It is undeniably true that many deaths have been caused by this agent, even when administered by competent and careful physicians, and, therefore, it should be remembered that *danger is inseparable from its use as a surgical anæsthetic.* The less number of deaths caused by this anæsthetic in the military service than what follows its use in civil practice is unquestionably due to the following: 1. More favorable atmospheric surroundings and a better physical condition of the patient; 2. A more competent and careful administration of the drug. Having briefly considered some of the points connected with the administration of the vapor of chloroform, as it pertains to operative surgery, we now turn our attention to sulphuric ether and its use as an anæsthetic. The most important objection to the employment of the vapor of ether by inhalation, is its pungent and somewhat disagreeable effects on the mucous membrane of the respiratory organs. The unpleasant qualities of this drug are certainly too insignificant to constitute a valid objection to its use with adults; and the plea, even in the case of children, is entitled to little consideration until it has been clearly shown that we are in possession of some other anæsthetic which is equally safe and more pleasant. Another objection to the use of this agent is, that it requires more time to bring a patient under its anæsthetic influence than is necessary when chloroform is employed. This objection cannot be controverted, although the rapidity with which a patient will be brought under the full anæsthetic influence depends greatly on the administration of the agent, which is commonly done in an unskilful and heedless manner. Time as a factor in connection with the administration of an anæsthetic, especially in military service, is entitled to consideration, since here the number of surgeons is always too small to be able to perform the required operations with that promptness which the exigencies of the case demand, and the delay caused by the use of ether instead of chloroform, would undoubtedly allow deaths to occur, which otherwise would have been avoided. The use of ether in surgi-

cal operations is entitled to our preference on account of its great safety. Dr. Snow says: "I believe that ether is altogether incapable of causing the sudden death by paralysis of the heart, which has caused the accidents which have happened during the administration of chloroform. I have not been able to kill an animal in that manner with ether, even when I have made it boil, and administered the vapor almost pure. The heart has continued to beat after the natural breathing has ceased, even when the vapor has been exhibited without air; and in all cases in which animals have been made to breathe air saturated with ether vapor, at the ordinary temperature of this country, they have always recovered if they were withdrawn from the vapor before the breathing ceased. Even in cases where the natural breathing has ceased, if the animal made a gasping inspiration after its removal from the ether, it recovered. I hold it, therefore, to be almost impossible that a death from this agent can occur in the hands of a medical man who is applying it with ordinary intelligence and attention."[1] I am aware of the fact that death has occurred in a few instances during the administration of ether, but it should be remembered in this connection that the occurrence of death prior to or during the performance of a surgical operation was not an unknown, or a very infrequent event, before anæsthetics were employed. These deaths were then attributed to fright, pain, or the combined influence of both. Sir James Y. Simpson has called attention to a case of this kind which occurred after anæsthetics were known, but where none was employed. The occurrence of death during the administration of ether has been so infrequent that it may be justly questioned whether this agent is chargeable with a single fatal case, but, nevertheless, the medical profession are not satisfied with chloroform or ether. They now seek to find some new anæsthetic agent which is more agreeable than ether and less dangerous than chloroform.

Dr. R. J. Levis, of Philadelphia, has recently called the attention of the profession to the anæsthetic use of the bromide

[1] Ibid. p. 362.

of ethyl, which is certainly more pleasant than sulphuric ether; but its safety is still very questionable. The rapidity with which its anæsthetic action is produced and the small quantity of the drug required to accomplish this result, would cause us to fear that the residuary vapor remaining in the lungs after the production of that degree of insensibility which would enable the surgeon to begin the operation might under certain circumstances become a source of danger. There is still required more experimentation and observation to determine the value of the bromide of ethyl as an anæsthetic. The various mixtures of chloroform and ether which have been hitherto much praised by some surgeons, I am satisfied ought never to be used. If the two agents must be used in the same case, the chloroform should be first administered to the patient until he is partially anæsthetized, and then the ether may be substituted, and afterwards continued for the purpose of maintaining the required degree of anæsthesia. In this manner it is possible to avoid the disagreeable properties, and the delay which would arise from the sole use of ether. I condemn these mixtures because I have learned from observation that *they are dangerous*. I can now call to mind four instances in which I have seen patients resuscitated with *much difficulty* after the administration of a mixture of chloroform, ether, and alcohol for the purpose of producing anæsthesia. These cases have produced a lasting impression on my mind, and I shall never again assume the responsibility of using that mixture. We ought under all circumstances to recognize the fact that the preservation of human life is more important than the pleasurable gratification of the patient, or a loss of time to the surgeon. Let not the surgeon therefore be influenced in the selection of an anæsthetic by its agreeable qualities or the rapidity of its action. This ought to be our general rule, and the only exception which I am willing to recognize, is to be found in the military service, on the field where the delay caused by the use of ether instead of chloroform, owing to the limited number of surgeons, would generally cause more deaths than the use of chloroform. Under these circumstances the use of chloroform is not only justifiable,

but also humane, although ether ought always to be employed in civil practice as a surgical anæsthetic.

In conclusion, we will briefly consider the question, how ought an anæsthetic to be given? Is the admixture of a large amount of atmospheric air with the anæsthetic during its administration advantageous? In the consideration of this question, it ought to be remembered that a sudden impression made on the system by the free use of a drug is commonly more effectual than its gradual administration, which quickly establishes a degree of tolerance. It is, therefore, probable that the proper administration of the vapor of chloroform with only a slight admixture of atmospheric air may produce the same degree of anæsthetic action when there is a smaller amount of the drug in the blood than would be required under other circumstances; but it should not be forgotten that there will remain in the lungs a proportionately larger quantity of this powerful medicine. It seems, therefore, that there is very little choice in regard to the rapid or slow administration of chloroform, since an unavoidable danger attaches to its inhalation by either method of procedure. Before the commencement of the administration of any anæsthetic the patient ought to be placed in the supine position, the pillow should be removed from beneath the head, which is allowed to rest on the same level as the shoulders, and other posterior portions of the body. The object of this position is to favor both the circulation of the blood and the administration of the anæsthetic. The latter is greatly aided by holding the cone perpendicularly to the face of the patient, while he is lying in this position instead of placing it at various angles, as is frequently done by the heedless assistant. The vapors of chloroform and ether are each much heavier than the atmospheric air, and hence the necessity of holding the cone in such a position as to allow it to fall directly over the mouth and nostrils of the patient. Furthermore, care should be taken to remove or loosen any portion of the patient's clothing which might interfere in the slightest degree with the circulation or respiration. Prior to the administration of the anæsthetic the patient should be tranquillized as far as possible, then urged to

breathe deeply with the intention of expelling as thoroughly as possible the residuary air contained in the lungs. The proper moment having arrived, the sponge, napkin, or other instrument saturated with ether or chloroform is carefully brought into the proper position to enable the gradual inhalation of its vapor to commence. The inhalation of any anæsthetic should always be cautiously commenced for the double purpose of avoiding any unnecessary irritation of the mucous membrane of the respiratory organs, and that the alarm which is otherwise so frequently seen to take possession of the patient at such times may be limited to its minimum.

I will now cite Sir James Y. Simpson on the administration of ether, much of which is equally applicable to the use of chloroform or other anæsthetic agents. He says: "*First*, the patient ought to be left as far as possible in a state of absolute quietude and freedom from mental excitement, both during the induction of etherization, and during his recovery from it. (The area of an hospital operation theatre is hence, perhaps, not the most favorable place for securing all the advantages of etherization, or rather for shunning all its disadvantages. Lately in a case in which Professor Miller performed partial amputation of the foot, in the Royal Infirmary, I etherized the boy who was the subject of it, in his bed in the wards. He was carried in this state up stairs to the operating theatre, the amputation performed and the patient brought back again to his bed before he was allowed to awake. He was thus, at one and the same time, entirely spared the moral shock and pain of being transported and carried in before a formidable collection of surgeons and students, and saved from the physical sufferings attendant upon the amputation itself; for he was perfectly unconscious of aught that had occurred, and, when he awoke, he was not aware that he had been operated upon, or had even left his bed. While being carried from the ward to the operating room, the sponge with which he was etherized was kept fixed over his face with a couple of common elastic letter bands. In our surgical hospitals, if a ward immediately adjoining the operation theatre were set aside for operations, it would in this

way facilitate the process of etherization, and insure more certain and perfect results from it.) All talking and all questioning should be strictly prohibited. In that way any tendency to excitement is eschewed, and the proper effect of the ether inhalation more speedily and certainly induced. And, *secondly*, with the same view, the primary stage of exhilaration should be entirely avoided, or at least reduced to the shortest possible limit by impregnating the respired air as fully with the ether vapor as the patient can bear, and by allowing it to pass into the lungs both by the mouth and nostrils, so as rapidly and at once to superinduce its complete anæsthetic effect. Latterly I have found that for surgical purposes, and when it is not necessary to keep up the etherization above five or ten minutes, by far the best and most perfect inhaler is formed by a large sponge of the common hollow conical shape, perforated artificially with a pretty large aperture at the apex, and placed over the face like a mask, so as to include both the mouth and nose in its concave base. At first, it should be held at a little distance from the face, and afterwards gradually advanced to it, in order to avoid exhibiting the vapor in too powerful and irritating a form for the first few inspirations. Its interior should, immediately before using it, be fully and freely saturated with ether, a very common but certainly a very unpardonable error being to exhibit an imperfect and exciting, instead of a perfect and narcotizing dose of the vapor. (When a prolonged effect is required, as in midwifery cases, an instrument is necessary, were it for no other reason than the saving of ether and the prevention of its diffusion through the apartment. Within the last few days I have seen a pamphlet dated Boston, May 30, 1847, in which it is stated that for three months previously, all apparatus had been laid aside, and the sponge alone used for etherization by Dr. Morton of that city, the gentleman to whom, I believe, the profession and mankind are really and truly indebted for first introducing into practice the production of insensibility, by ether inhalation, with the object of annihilating pain in surgical operations. See *Some Account of the Lethean Action of Ether*, by Edward Warren, p. 87.) Many of the alleged failures and mis-

adventures are doubtless entirely attributable to the neglect of this simple rule; not the principle of etherization, but the mode of putting it in practice being altogether to blame. But, *thirdly*, whatever means or mode of etherization is adopted, the most important of the conditions required for procuring a satisfactory and successful result from its employment in surgery, consists in obstinately determining to avoid the commencement of the operation itself, and never venturing to apply the knife until the patient is under the full influence of the ether-vapor, and thoroughly and indubitably soporated by it."[1]

The application of the tourniquet ought not to be attempted until the patient has been rendered sufficiently insensible so as to be undisturbed by the necessary manipulation. The *choice of this instrument* must chiefly depend on the point at which the amputation is to be made, the condition of the limb, and the general state of the patient's health. Amputations of the fingers and toes do not require the use of a tourniquet, since the assistant may easily compress the bleeding vessels, and thus completely arrest the flow of blood. Disarticulation at the hip and shoulder requires special means for the control of the blood during the performance of the operations; but the

Fig. 9.

Gross's artery compressor.

most of these measures have been already mentioned and more or less fully described in this work. It will therefore suffice

[1] Anæsthesia, etc., New York, 1872, p. 174 *et seq.*

that we introduce the following figures, which, on account of their simplicity, require no additional explanation :—

Fig. 10.

Fig. 11.

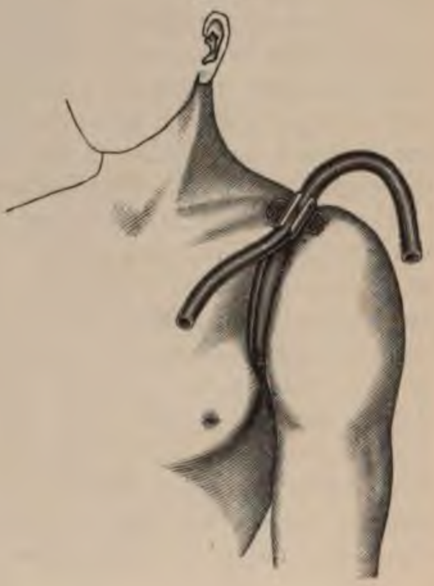


Fig. 10.—Application of the elastic tube in disarticulation at the shoulder-joint.
Fig. 11.—Application of the self-retaining elastic tube in disarticulation at the shoulder-joint.

The circulation of the blood is commonly controlled during the performance of all amputations, either in the continuity or the contiguity, except at the hip- and shoulder-joints, by Petit's tourniquet, Esmarch's aortic apparatus, or some modification of the same. The following illustrations represent the instruments in common use. (Figs. 12, 13, 17.)

It has already been suggested that the selection of the apparatus for the control of hemorrhage during the performance of an amputation ought, in certain cases, to depend on the condition of the patient. In all cases of anæmia, or a deficiency in the quantity of blood, the patient ought to have the benefit of

Esmarch's apparatus. The proper application of this apparatus reduces the loss of blood during the performance of an amputa-

Fig. 12.

Pancoast's aortic compressor.

Fig. 13.

Esmarch's aortic compressor.

tion to the minimum, which need not exceed in ordinary cases a single drachm. The application of the elastic bandage of this apparatus, which begins at the fingers or toes, is much in precisely the same manner as the ordinary roller bandage, until that point is reached where it is intended to apply the tourniquet, and here

the bandage is reversed and carried downwards for the purpose of facilitating its removal. The elastic tubing having been

Fig. 14.

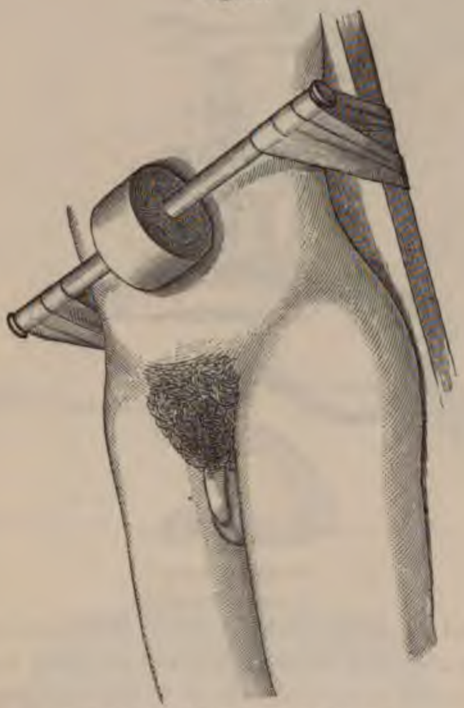
Fig. 15.

Fig. 14.—Application of Esmarch's aortic compressor.
Fig. 15.—Aortic compression with roller-bandage and the elastic band.

applied over the upper portion of the bandage in such a manner as to prevent the return of blood to that portion of the limb from which it has already been driven, the removal of the elastic bandage is the next step in the procedure. The degree of tightness required to accomplish the object sought to be gained by the use of both the bandage and tubing is much less than is generally imagined by surgeons, and hence we often see them making a physical effort, which is worse than useless during its application. The next question which presents itself for our consideration is that involved in the PREPARATION OF THE LIMB. The preparation is prompted by the surgeon's desire to give the patient the best possible chance for recovery, and at the same

time as much freedom from pain as is consistent with the performance of the operation, and, also, to facilitate the operative

Fig. 16.



Brandis's method of compressing the aorta.

procedure. There are certain cases in which the surgeon may not be prepared or desire to employ Esmarch's apparatus, although anxious to diminish as much as may be practicable under the circumstances the loss of blood. This object may be readily accomplished by raising the limb above the level of the patient's body as much as may be convenient, and then firmly stroking it with the hand from the toes or fingers, as the case may be, for some minutes, after which the tourniquet may be applied. Unquestionably this simple procedure may considerably lessen the loss of blood in amputation of the extremities.

There are also many cases where a proper regard for the patient's comfort renders it absolutely necessary that the limb should be

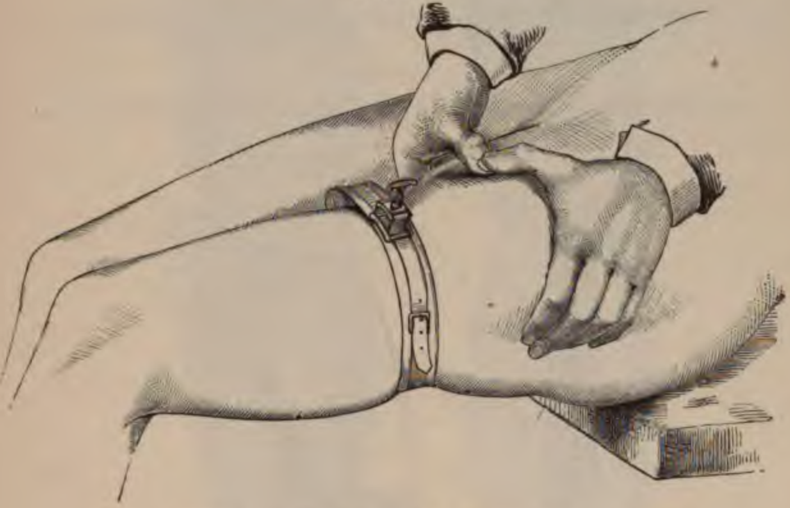
Fig. 17.

Petit's tourniquet.

closely shaved for some distance above and below the point at which the operation is to be performed in order to remove the hair, which would otherwise adhere to the dressings and give rise to much pain whenever it became necessary to remove the same. In fact, we are fully satisfied that this process ought not to be neglected in any amputation of an extremity, except the operation be limited to the fingers or toes, inasmuch as it also promotes cleanliness about the wound, a condition of much importance, and one which should always be maintained. In this connection it ought to be remembered that the performance of an amputation in accordance with the requirements of the antiseptic practice demands that the limb shall be closely shaven, carefully washed with soap and water, then washed with the 1–20 carbolic acid solution, and afterwards with pure sulphuric ether; and, furthermore, the surgeon is strictly enjoined against

using sponges or cloths in this practice, but instead of them he is required to employ the chemically pure nail-brush. In certain

Fig. 18.



Pressure with the thumbs. Application of tourniquet to femoral artery.

Fig. 19.

Esmarch's elastic apparatus.

wound lesions an assistant having been requested to take charge of that portion of a limb which is to be amputated should call for a napkin, bandage, or other suitable article with which he will proceed to envelop the limb in order that his hands and

clothing may not be smeared with the wound secretion while performing his duty. It may be a question whether the shaving

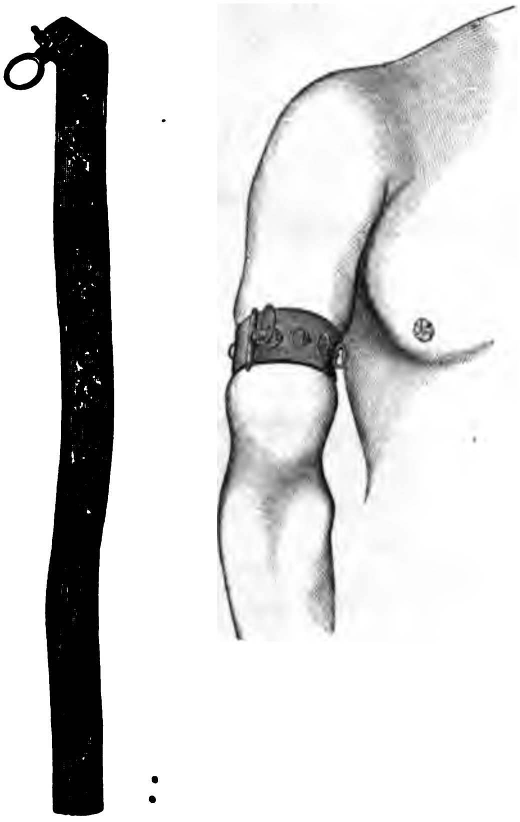
Fig. 20.

Application of Esmarch's elastic apparatus. (See colored plate opposite.)

Fig. 21.

Appearance of the limb after the removal of the bandage. (See colored plate opposite.)

Fig. 22.



Nicaise's elastic band or tourniquet. Fastened by a hook and ring.

and cleaning of the limb ought to be done before or after the administration of the anæsthetic. The shaving may be properly

Fig. 20.

Fig. 21.

performed before the anæsthetic is given, unless the movements of the limb required in this procedure are too painful, but the cleansing is always preferably delayed until just prior to the commencement of the operation; and in the *antiseptic practice it ought never to commence until the spray has begun to play on the surface to be cleansed.* The administration of the anæsthetic, the selection and application of the tourniquet, the preparation of the limb, and the selection and arrangement of the instruments, ought to be performed at about the same time.

THE SELECTION AND ARRANGEMENT OF THE INSTRUMENTS must in a measure depend on the method of operative procedure. The performance of an amputation in accordance with the rules of antiseptic surgery requires in addition to those otherwise employed the following instruments: an atomizer, twisting forceps, and shield, which are illustrated in the following wood-cuts:—

It has been recently demonstrated that the most efficient atomizer is not that *instrument, which delivers the finest spray,* and consequently inconveniences least the operator by drenching and benumbing his hands. The process of *spraying only destroys the germs when they are wet,* and the efficiency of the spray depends as much on the formation of a continuous layer of carbolic solution over the wounded surface, the surgeon's hands, instruments, and other surrounding objects as on the purification of the air. It therefore follows that the spray must necessarily contain enough of the solution to promptly and effectually wet any substance with which it may come in contact, in order to secure efficacious results. The atomizer which throws a spray that neither benumbs the operator's hands, nor otherwise inconveniences him, may have its proper place as an amusing toy, but should not be found in a collection

Fig. 23.

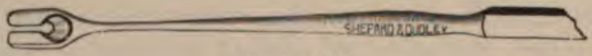
Lister's steam atomizer.

of surgical instruments. Another point ought to be taken into consideration in the selection of an atomizer, viz., the capacity

Fig. 24.

Emmet's twisting forceps.

Fig. 25.



Sims's shield.

of the boiler and the spirit lamp. Their capacity ought to be such that it would not become necessary to refill either during the performance of an ordinary operation. In fact the atomizer ought to remain in continuous action two hours without requiring attention to either the boiler or spirit lamp. The use of the spray by means of the steam atomizer is undoubtedly the most convenient and reliable method which has yet been adopted for the protection of the wound during the performance of an operation, but unquestionably the same object might be equally well accomplished by systematic irrigation. The twisting forceps and shield are required in the practice of antiseptic surgery whenever metallic wire is employed for the purpose of closing the wound, but these instruments and their use have been so frequently described by Drs. Sims, Emmet, and others, as to require no further attention. The amputating knife which is to be employed in any particular amputation is selected in the first instance with especial reference to the locality of the operation, and secondly in accordance with the fancy of the surgeon: although it may be here stated as a general rule that the greater the diameter of the limb at the point where the operation is to be performed the longer should be the knife. We therefore find that amputations of the fingers and toes are commonly performed with a scalpel, while Liston's long amputating knife is generally preferred in amputations of the thigh. The amputating knife, whether long or short, ought to be well bal-

Fig. 26.

Fig. 27.

Fig. 28.

Fig. 29.

Fig. 26.—Liston's long amputating knife. Fig. 27.—Liston's medium amputating knife.
Fig. 28.—Scalpel, or finger knife. Fig. 29.—Catlin, or double-edged knife.

the bandage is reversed and carried downwards for the purpose of facilitating its removal. The elastic tubing having been

Fig. 14. Fig. 15.

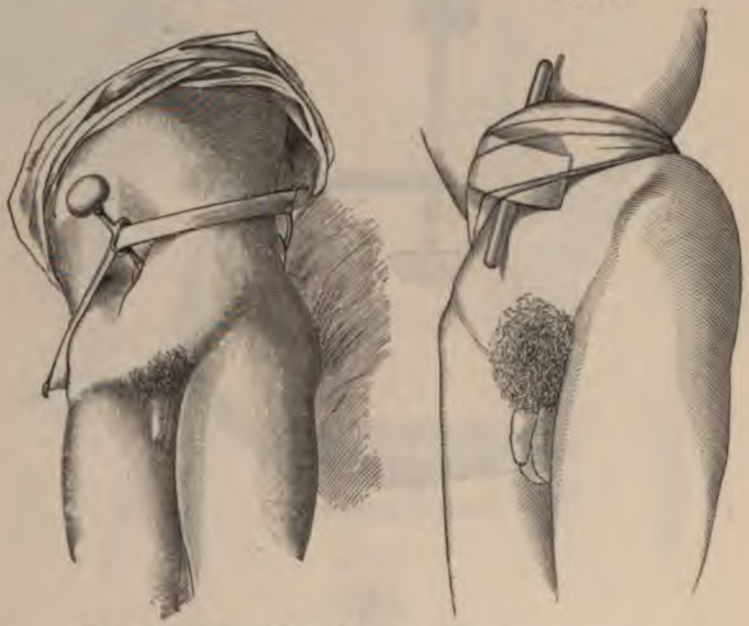
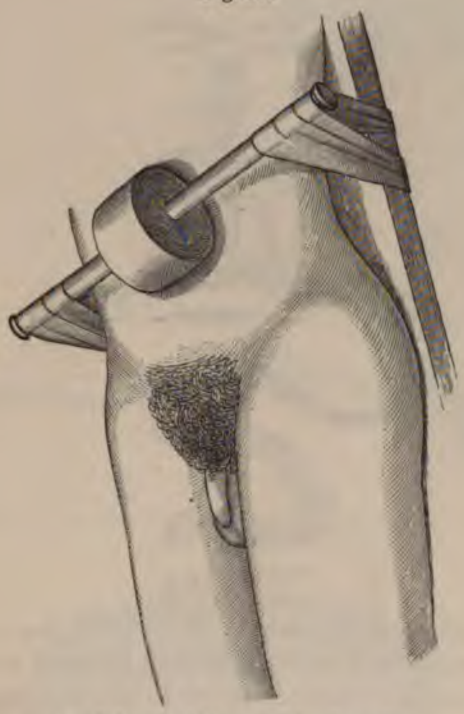


Fig. 14.—Application of Esmarch's aortic compressor.
Fig. 15.—Aortic compression with roller-bandage and the elastic band.

applied over the upper portion of the bandage in such a manner as to prevent the return of blood to that portion of the limb from which it has already been driven, the removal of the elastic bandage is the next step in the procedure. The degree of tightness required to accomplish the object sought to be gained by the use of both the bandage and tubing is much less than is generally imagined by surgeons, and hence we often see them making a physical effort, which is worse than useless during its application. The next question which presents itself for our consideration is that involved in the PREPARATION OF THE LIMB. The preparation is prompted by the surgeon's desire to give the patient the best possible chance for recovery, and at the same

time as much freedom from pain as is consistent with the performance of the operation, and, also, to facilitate the operative

Fig. 16.



Brandis's method of compressing the aorta.

procedure. There are certain cases in which the surgeon may not be prepared or desire to employ Esmarch's apparatus, although anxious to diminish as much as may be practicable under the circumstances the loss of blood. This object may be readily accomplished by raising the limb above the level of the patient's body as much as may be convenient, and then firmly stroking it with the hand from the toes or fingers, as the case may be, for some minutes, after which the tourniquet may be applied. Unquestionably this simple procedure may considerably lessen the loss of blood in amputation of the extremities.

always be threaded with wire or silk before the commencement of the operation so that there may be no unnecessary delay in closing the wound. The performance of an amputation under the antiseptic precautions generally precludes the use of retractors. This portion of the operation can ordinarily be just as effectually performed with the hands of an assistant without the aid of instruments; but in those cases where their use is not objectionable they may still be employed as a matter of convenience. The performance of the subperiosteal amputation will require in addition to the instruments which have been previously mentioned the use of strong forceps to steady the bone, especially while the surgeon is making the last section with the saw. The selection of the instruments having been made by an assistant, and afterwards inspected by the surgeon to make sure that everything which may be required for the operation is in readiness, should now be arranged on a table, in a tray, or pan of some sort where they may be kept constantly covered with the 1–20 solution if the operation is to be performed antiseptically; and at that distance from the operator which best suits his convenience. If the surgeon has no assistant to hand the instruments as they may be required, then it will be necessary that the table or tray shall be so placed that the operator may be able to pick up the required instruments without even changing his position. Finally it remains to be added that the surgeon before he commences the performance of an amputation ought to carefully study the entire surroundings of the case, and then arrange the instruments and other details in such a manner as to facilitate as much as possible the operative procedure.

It is not always in the power of the surgeon to regulate the number of his assistants, and since their respective duties must necessarily depend on their numerical strength, it therefore follows that only general rules on this subject can possess any practical value. In the major amputations of the arm, forearm, thigh, or leg, four or five assistants and a nurse may be advantageously employed as follows: one in charge of the administration of the anæsthetic; one in charge of the tourniquet, ligatures, and retractors; one in charge of the instruments and

sponges; one in charge of the atomizer in those cases where the spray is employed; and another in charge of that portion of the limb which is to be amputated. The efficient discharge of the respective duties of these assistants will keep them fully employed during the performance of the operation, while the nurse, who at such times may be properly regarded as the man-of-all-work, ought in the first instance to assist in bringing the patient into the operating room, then he aids in the removal of so much of the patient's clothing as may be required for the safe administration of the anæsthetic, or the performance of the amputation, aids in placing the patient in the proper position, and while the administration of the ether is going on, assists in restraining the patient during the period of excitement, which, being over, he immediately seizes hold of one or two napkins which he places over his arm or shoulder, and is now in readiness to hold a light, to pass to the operator or either of the assistants a towel or basin of water, or in fact to perform any similar duty which may arise from the exigency of the case. The assistants having assembled in the operating room prior to the commencement of the operation, ought to be constantly on the alert and anticipate every wish of the operator, who ought not now to make any physical effort, such as may be required to bring the patient into a proper position for an amputation, or to restrain him during the administration of the anæsthetic. The effect of these physical efforts on the operator are twofold: first, his attention is diverted from the contemplation of the various details of the operation; and, secondly, they may render his hand unsteady, and thus incapacitate him in a degree for handling properly the required instruments. Before the assistants are assigned by the operator to their special duties, each should endeavor to make himself generally useful; but after this assignment has been made, then each should give his *entire attention to the performance of his own duties.* Perfect quietude should be maintained, and no conversation should be indulged in except that which relates to the operation in hand. The duty of the assistant who administers the anæsthetic is a most responsible one. He should carefully watch the state of

anæsthesia in which the patient is placed as manifested by the circulation, respiration, and other symptoms. He should endeavor to maintain upon the patient a uniform effect of the agent used, and under no circumstances should he leave the patient or take part in any of the other duties of the operation. The assistant having charge of the tourniquet should carefully watch the effect of the anæsthetic on the patient in order that he may have completed the application of this instrument before the patient is sufficiently under the anæsthetic influence to justify the surgeon in making the first incision. The application of the tourniquet while the patient is only partially under the influence of the anæsthetic ought never to be a source of pain to the patient or a delay to the performance of the operation. The same assistant who has carefully applied the tourniquet, is now in the proper position to render efficient service to the operator by the retraction of the flap, and the bone having been cut through, he is again in the right place to assist in the ligation of the arteries. It is unnecessary to proceed farther with these details; however, it should be thoroughly understood that every operator expects of his assistants strict attention to their duties and prompt action. The performance of minor amputations do not require the same number of assistants, although the same general rules are equally applicable, and furthermore the same principles are also to be applied when major amputations are performed with fewer assistants.

THE POSITION OF THE PATIENT AND OF THE OPERATOR may be briefly stated as follows: the patient should be placed in the recumbent posture, and the extremities so arranged as to afford the surgeon the best possible opportunity for the performance of the operation, and the operator should take a position which gives perfect freedom to all necessary movements without causing any unnecessary fatigue or other source of embarrassment. The table should be firm, and the height such that the operator need not be constantly stooping during the performance of the operation. Unquestionably, the greatest freedom of motion is found in the standing position, and consequently operators prefer this position for all major amputations.

Sawing the Bone.—The flaps having been formed, the next step in the operation consists in clearing the bone for the application of the saw. This part of the operation is preferably done with a scalpel, instead of using an amputation knife, since it would certainly result in dulling and possibly otherwise damaging a valuable instrument when a cheaper one would answer equally well. The assistant, for the purpose of aiding the surgeon in clearing the bone, seizes the flaps and draws them strongly upwards, and now the operator carries the scalpel from heel to point around the under segment of the bone, and afterwards around the upper surface in the opposite direction. When there are two bones care must be exercised in clearing them not to carry the edge of the knife in the interosseous space above the line where the saw is to be applied, lest an artery be cut, which, after its retraction, it would be difficult to secure. The bone having been carefully cleared at the point where the saw is to be applied, the heel of the instrument is now placed on it The operator ought now to examine carefully the relative position of the saw to the bone which he is about to cut. He may in this way avoid cutting the bone obliquely, or in such a manner as afterwards to cause, for himself, mortification, if nothing more serious. Having assured himself that the position of the saw is satisfactory, he now presses it firmly against the bone and steadies it with the left thumb, while the instrument is drawn from heel to point over the bone, and a deep initial groove is thus made in it. He now carefully maintains the same relative position of the saw to the bone, and quickly completes the sawing, which is done with long strokes instead of short ones, whilst the position of the saw is gradually changed from the horizontal to the vertical as progress is made. The assistant should now carefully support the part to be removed; neither depressing it so as to snap the bone as it is weakening by sawing, nor raising it, which may lock the saw. During the sawing of the bone, the assistant in charge of the flaps should be very careful that the teeth of the saw do not come in contact with the muscles, in which the bone-dust might thus become imbedded in such a

manner as to escape the attention of the surgeon, and which if allowed to remain behind would certainly interfere greatly with the process of healing. Should the division of the bone be made in such a way as to leave projecting splinters, these must be snipped off with the cutting pliers.

Arrest of Hemorrhage.—There is presented in the first chapter of this work a very full *résumé* of the various means employed for the control of hemorrhage during and after the performance of amputations. Consequently there remains very little to be said on this subject here, beyond expressing my individual preference of the means to be employed for the accomplishment of this object. It can no longer be denied that the ligature is the safest as well as the most convenient means now known to surgeons for the control of hemorrhage after the performance of amputations. The old objection, that the ligature is a foreign body in a wound which frequently excites irritation and inflammation, and may even occasionally cause septic infection, is now wholly remedied by the use of carbolized catgut ligatures; which during the last few years have been extensively employed, being cut short and left in the wound. Their employment has been found entirely satisfactory when a good article has been used, even in cases where the antiseptic method has not been adopted. We, therefore, unhesitatingly recommend the ligation of all the arteries, the hemorrhage from which cannot be readily controlled by torsion, with the catgut ligatures when a good article can be obtained. In those cases where the catgut ligatures cannot be had, silk thread may be substituted for them. If the silk ligatures are employed in the antiseptic method, they should be first thoroughly carbolized, and even then it is not well to cut them short and leave them in the wound; but in *all cases where silk is employed, one-half of each ligature should* be cut off close to the knot, and the single threads thus left must be brought out at one of the angles of the wound. In use of wire as ligatures I have no experience; but Mr. Erichsen says on this subject: "I have employed wire in several instances, but have found that it does not cut through the artery as the thread does, and consequently does not detach

itself, but requires to be pulled or twisted off—a procedure which may be attended by hemorrhage. The practice of cutting the ends of ligatures short, whether hempen or metallic, is most objectionable; for, although the stump may heal over them, they eventually become sources of irritation, and set up suppuration or develop neuralgia."[1] The proper application of the ligature requires that the artery should be seized with the artery forceps, or tenaculum, and drawn forwards; that it should then be carefully separated from the surrounding tissues, after which the ligature should be passed around it and firmly knotted. The practice of including within the ligature with the artery the surrounding tissues is frequently a source of much pain to the patient and annoyance to the surgeon, besides being a very bungling procedure. The hemorrhage which occasionally arises from a cut surface of bone, in consequence of the division of a nutrient artery, may generally be controlled by the application of a compress over the bleeding parts. The temporary application of a compress in the majority of cases is sufficient to control this hemorrhage; but should the bleeding continue so long that the surgeon finally concludes to close the wound and leave the compress behind, he may attach to it a wire by which it may be removed at the pleasure of the operator, the ends of the same having been brought out of the angle of the wound for the purpose of facilitating this procedure. It is a matter of great importance that all bleeding after the performance of an amputation should be effectually controlled before the wound is closed, and a strict adherence to this point frequently saves the patient much pain, and the surgeon much annoyance.

Drainage-Tubes.—The introduction of a drainage-tube into an amputation wound before it is firmly closed may be regarded as the offspring of Prof. Lister's antispetic wound-treatment, and since it is based on a sound surgical principle, and as it is unquestionably a marked improvement over the old method of hermetically sealing a wound after this operation, therefore it should not in any case be omitted. The advantages of free

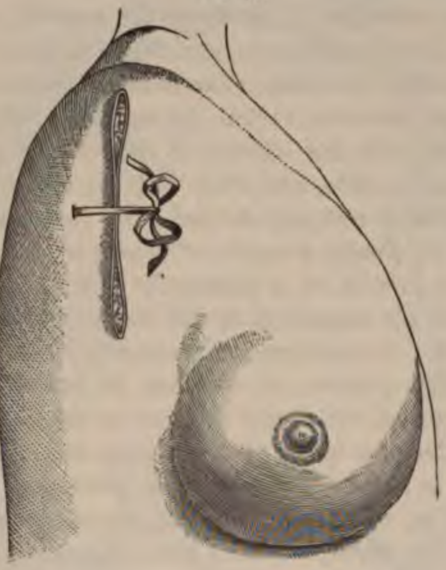
[1] Science and Art of Surgery, Phila., 1878, vol. i. p. 69.

drainage in cases of amputations when viewed from an antiseptic standpoint are too valuable to be lost sight of, or even seriously questioned. The very fact that free drainage may be secured after every amputation, and *that it greatly diminishes* the dangers of septic infection, gives additional interest to the means employed for the accomplishment of this object. The rubber drainage-tubes which are now commonly employed are about one-fourth of an inch in diameter, and are supplied with numerous lateral openings which give admission to the wound-fluids. The tubes should be introduced in such a way that gravity will assist in emptying them, and care should also be taken that they are not closed by being pressed against bone or other unyielding substances. The tubes having been introduced and the wound closed, it now becomes important for their usefulness that something should be done to avoid their slipping from the wound, or being compressed external to it by the dressing. Both these objects are readily accomplished by the passage of fine cambric needles through both ends of the tubing in such a manner that they may rest lightly on the integument, after which the tubing is cut off externally to these needles, but as closely as may be done without liberating them. It now remains to be shown that the tube, since only one is commonly employed in these cases, is open throughout its whole length and in a condition to do its work satisfactorily. This is easily shown by throwing a carbolic-acid solution through the tube by the aid of a syringe.

THE CLOSURE OF THE WOUND.—Prof. Carl Ferdinand Graefé, of Berlin, published in 1812 a work entitled *Normen für die Ablösung grosserer Gliedmassen nach Erfahrungsgrundsätzen entwerfen*, from which we copy, Fig. 35. It is presumed to represent accurately the appearance of an amputation wound at the shoulder-joint, after its closure with the fillet in accordance with the practice which had long been prevalent. The use of the fillet has been abandoned, and we now commonly employ for the purpose of maintaining the approximation of the flaps the well-waxed silk or metallic suture, although the latter is unquestionably decidedly preferable. I now employ the fine

iron wire commonly used by florists in their preparation of bouquets and other arrangement of flowers, and even prefer it as a suture to the best silver wire. The old objection which has been so long urged against fine sutures being liable to cut

Fig. 35.



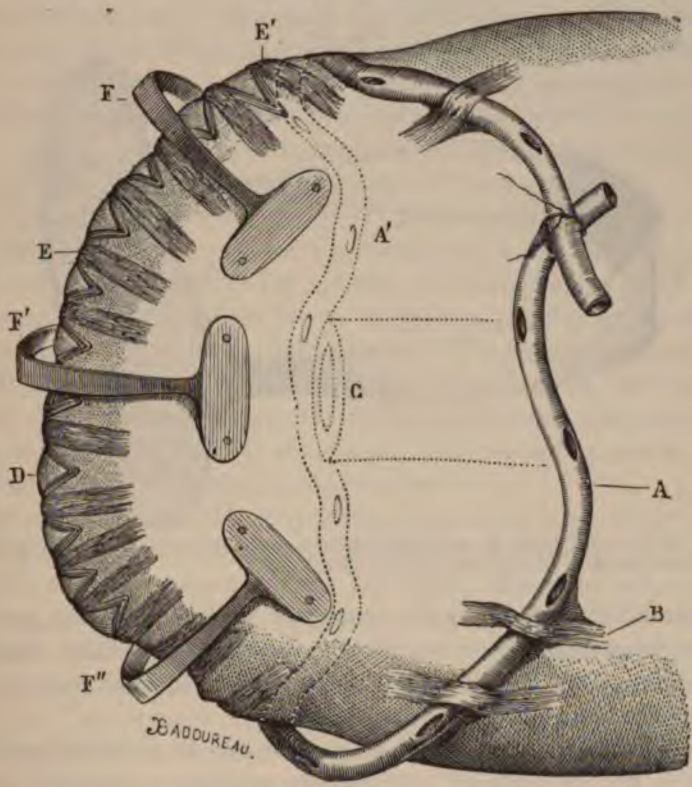
through the integument is not entitled to any consideration when a metallic wire is employed. The coarse silk suture is much more liable to make its way through the integument by the aid of the suppuration which it excites than is the finest wire, the former being always a source of irritation whilst the soft parts kindly heal around the latter. The surgeon should keep constantly in mind the fact that sutures are employed for the purpose of preserving continuous contact between the flaps, and since the more perfectly this object is accomplished the better will be the prospect of union by first intention, consequently much pains should be taken in the performance of this part of the operation. Every operator should recognize the fact that in each operation the conditions effecting the preserva-

tion of contact between the flaps are essentially different, and consequently the distance between the sutures, as well as their depth, must be regulated by the circumstances of each individual case. The time for the removal of the sutures must also be regulated by the condition of the parts, for instance, the accumulation of wound-fluid between the flaps which cannot otherwise be evacuated, necessitates the removal of a suture as soon as the discovery is made, and this conclusion is reached, whilst under more favorable circumstances the wire suture may remain in the parts for weeks. In removing the sutures they should be cut with the scissors at the side as closely to the integument as possible, and when they are withdrawn it should be *accomplished by carrying the end of the suture which has been seized with the forceps towards or even over the cicatricial line,* and not away from it, as is commonly done, while the borders of the wound are supported by the thumb and index-finger of the free hand. Compresses are frequently advantageously employed for the purpose of assisting in maintaining contact, especially between the deeper portions of the cut surfaces, and the application of a splint to the stump may diminish greatly the liability to a disturbance of these parts due to motion, as well as aid in the preservation of contact. The following illustration, Fig. 36, represents a plan which has been employed in France to make methodical compression in order to aid in procuring union by first intention.

The accompanying figure (Fig. 36) of almost natural size, represents the pincers employed to secure the deep approximation of the parts. Compresses, pincers, etc., are seldom required except where the bone is very large, as the femur, and where an angle is left between the flaps at the apex of the stump, which, by preventing complete coaptation at this point, renders their application necessary; so also, if a cavity exists in the bone, as the glenoid or cotyloid, in amputation at the shoulder and hip. Strips of adhesive plaster are also employed by the majority of surgeons for the purpose of assisting the sutures in maintaining the contact of the parts. When used they should be carefully applied that they may not interfere with the discharge of the

wound fluids, disturb or pull out the sutures when they are removed. It is now several months since I have employed this

Fig. 36.

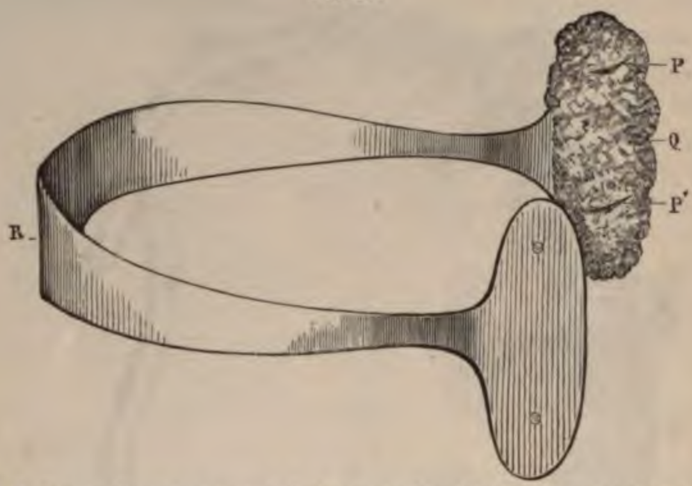


A, A'. Drainage-tube within and external to the wound. *B*. Collodionized charpie employed to keep the drainage-tube in its place. *C*. Division of the femur, its relation to the drainage-tube. *D*. Threads of the twisted suture which remain in place after the extraction of the pins. *E, E'*. Bundle of collodionized charpie strengthening the suture. *F, F''*, F'. Pincers used to secure the deep approximation.

agent in any major amputations, and am thoroughly convinced that the proper use of fine iron wire sutures renders the application of strips of adhesive plaster worse than useless. The closure of the flaps having been neatly effected the next step in our procedure is the application of the dressing. It is quite

immaterial whether Lister's or some other method be employed. A bandage should always be firmly applied in every case from the upper portion of the limb down to the end of the stump, which materially aids in supporting the flaps, preserving their

Fig. 37.



P, P. Very small points to prevent the instrument from slipping off. *Q.* Agaric surface to protect the skin. *R.* The force regulated by the spring.

contact and diminishing the spasmodic twitchings of the parts. The stump should now be slightly elevated, comfortably placed on pillows, steadied in its position by sand bags, and protected from the bedclothes by a cradle.

Double Amputations.—The performance of a double amputation may be rendered necessary by accident or disease; and there are certain questions which arise in connection with this operation which do not pertain to single operative procedures. The most important however is, shall both limbs be amputated at the same time, or shall there be an interval of some days between the first and second operations. The old surgeons were in favor of an interval of five or six days; but the more modern pursue the opposite course for reasons which are very forcibly expressed by Prof. S. D. Gross, who says: "This constitutes what is termed the synchronous double operation.

It is founded upon the assumption that the recovery is more rapid when two limbs are cut off simultaneously than at two separate and distinct periods; that the loss of blood will be comparatively little more from two amputations thus performed than from one alone; that there will be in the aggregate much less pain, shock, and inconvenience; and, lastly, that the patient will thus escape the harassing anxiety of mind growing out of the knowledge that he will be obliged to submit to another operation."[1] Ferguson has mentioned a case in which at the same moment both limbs were removed by two surgeons; but there is certainly no longer any necessity for such precipitate haste. The efficiency of the means now employed for the control of hemorrhage gives the operator an abundance of time to accomplish the removal of two or more limbs without a material increase of danger to the patient's life. The question of prognosis in double amputations must be determined by the same general rules as are applicable to single operations. Experience has, however, shown that the danger to life is not increased in proportion to the number of amputations.

REAMPUTATIONS.—These operations may become necessary on account of certain diseased conditions of the stump, among which may be mentioned the following: extensive necrosis, ulceration of the soft parts, great retraction of the skin and muscles leading to protrusion of the bone, and hypertrophy of the nerves attended with neuralgia and exquisite morbid sensibility. The necessity for this operation as well as its performance should be strictly regulated by the rules which have already been given for amputations.

THE RESULTS OF AMPUTATIONS OF THE EXTREMITIES ON THE PHYSIOLOGICAL FUNCTIONS AND ON LONGEVITY.—It is unquestionably true that in many cases the amputation of an extremity, especially for a traumatic injury, has been followed by obesity. This obesity has often seemed to be proportionate to the amount of tissue removed, and becomes more marked after the performance of double amputations. Having performed this

[1] System of Surgery, Phila. 1866, vol. i. p. 512.

(double) amputation twice sucessfully within eight years, I have now two living examples. The first operation was performed on a mechanic aged 22, for frost-bite, through the middle third of each leg. The weight of this patient before the operation was about 135 pounds, but six years after the performance of the same he weighed 240 pounds. The other patient was a laborer about 35 years old. The operative procedure consisted of a disarticulation at the shoulder, and an amputation through the middle third of the thigh; and, notwithstanding the fact that this patient lost by these operations a considerable portion of his body, it only required about two years for him to regain the weight of his lost limbs, and add one hundred pounds to his heaviest weight prior to the occurrence of this accident. There have been assigned two reasons for these marked changes which are certainly frequent concomitants of the removal of an extremity. The one accounts for this condition of obesity on the basis of physical inactivity, while the other attributes it to an increased power of digestion and assimilation. It is probable that both these factors are co-workers in the large majority of cases. Associated with this condition of obesity there are frequent derangements of certain physiological functions. Attacks of epistaxis may become frequent, hæmorrhoids are apt to develop, perspiration and the other secretions are commonly more copious, while females often suffer from menorrhagia. The older physicians, for the purpose of avoiding these diseases as well as the other evils and dangers arising from the plethoric condition of their patients, were accustomed to recommend the periodical performance of phletobomy; but the same object is now accomplished by a more direct and efficacious method. The modern physician now primarily seeks to remedy these evils and dangers by the increased activity of his patient; and, secondarily, by regulating as far as possible everything pertaining to his alimentation. It should be remembered that the tendency to obesity is greatly modified by age. The old recover slowly from the effects of an operation, and the ordinary growth of children prevents them from becoming corpulent. It has been further observed that if an amputation is necessitated

by a chronic disease, such as white swelling, exostosis, scrofula, constitutional syphilis, cancer, or certain forms of gangrene, instead of the patients exhibiting a tendency to become corpulent, it is not infrequent for them to remain emaciated, although many recover, at least temporarily, their former good health. A knowledge of these facts which have been stated, may aid the surgeon in forming his prognosis, besides possessing more or less practical value as a basis for medication; but every case ought to be carefully examined prior to the performance of an amputation for the purpose of discovering any complication which may exist. Our study of the effects of amputations of the extremities on the physiological functions have brought us to the same conclusion as was reached by Messer, upon an examination and comparison of statistics. This author concludes that those who have lost limbs do not obtain so great an age as those who have not.

CHAPTER V.

SPECIAL AMPUTATIONS OF THE SUPERIOR EXTREMITY. AMPUTATIONS OF THE HAND, FOREARM, AND ARM. AMPUTATIONS AT THE WRIST, ELBOW, AND SHOULDER-JOINT.

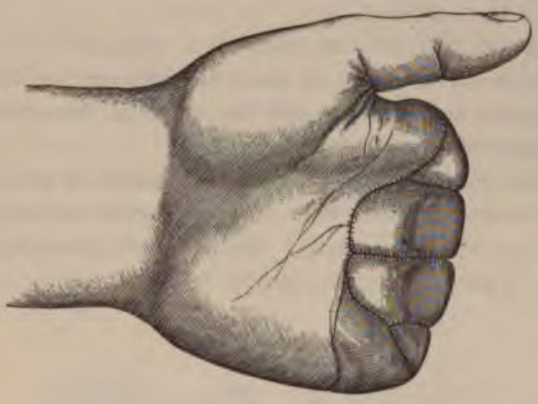
SPECIAL AMPUTATIONS OF THE INFERIOR EXTREMITY. AMPUTATIONS OF THE FOOT, LEG, AND THIGH. AMPUTATIONS AT THE ANKLE, KNEE, AND HIP-JOINT.

WE have already mentioned various methods of amputating limbs, viz., circular, flap, oval, elliptic, and rectangular, also briefly called attention to some of the advantages and disadvantages of the different operative procedures; but we shall hereafter attempt to supply such hints in connection with a specific description of the performance of each operation as it is thought may be serviceable. Undoubtedly a skilful surgeon may be able to produce satisfactory results by either of these methods; but it is very desirable that he should be able to practise all. Although in many cases, one method may be as applicable as another, yet under certain circumstances it may be advantageous to depart from the method usually adopted and employ one of the others. In determining the method of operative procedure the surgeon ought to be governed by the circumstances of the case before him. It is comparatively easy to supply precise rules for the performance of an amputation through sound structures; but a departure from these is frequently made unavoidable by an irregular destruction of the tissues by injury or dsease. In illustration of this principle of conservative surgery we will call attention to the following wood-cut (Fig. 38).

This figure represents accurately the appearance of a hand after the AMPUTATION OF ALL THE FINGERS and the closure of the flaps, which was rendered necessary by an accident involving the osseous tissues down to the metacarpo-phalangeal articula-

tions, together with the integument and soft parts over the whole anterior portion of the fingers as well as a large portion of the palmar surface. The destruction of the soft parts had been so great that it was impossible to obtain either anterior or

Fig. 38.



lateral flaps, but the integument over the posterior surface of the fingers was still available for this purpose. We therefore proceeded to amputate at the metacarpo-phalangeal articulations, carefully preserving sufficient integument from the posterior surface of the fingers to supply the whole of that which had been destroyed. The wound on the palmar surface of the hand was now thoroughly cleaned, the tissues which had been so severely injured as to destroy their vitality were removed with the scissors or scalpel, after which the flaps were neatly adjusted over the parts and secured by the iron wire sutures. The result of this operation was entirely satisfactory. The wound healed kindly without any sloughing of the flaps or other unfavorable complication. Mr. Erichsen has called attention to the following important operative procedure:—

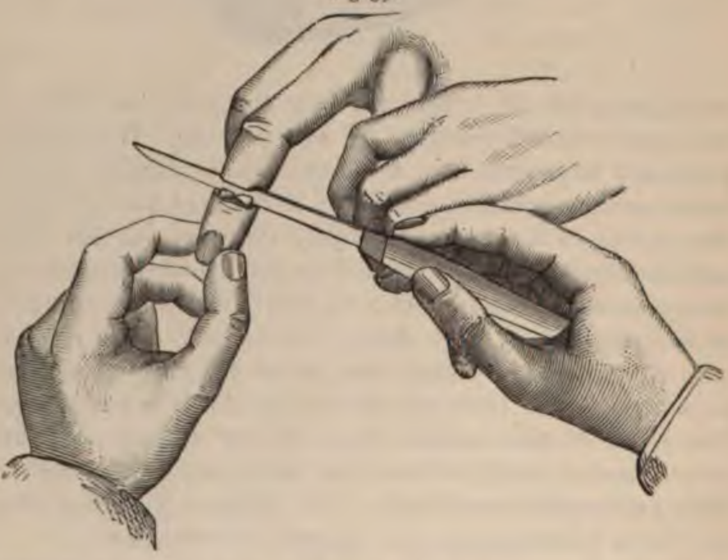
"IN MANY CASES THE UNGUAL PHALANX BECOMES NECROSED, AND MAY USUALLY MOST READILY BE REMOVED WITHOUT AMPUTATION, by making an incision through the pulp of the finger, and then extracting the diseased bone, thus saving the nail and

pulp, which will form an excellent end to the finger; and, if the operation be done in early childhood, a new and movable phalanx may form."[1] In disease of the bone from whitlow such a proceeding is generally practicable, and consequently it is only when the parts have been crushed by machinery or some other cause, that the amputation of the finger will be required at the last joint.

THE AMPUTATION OF THE TERMINAL PHALANX OF A FINGER may be variously modified to meet the different indications in any particular case; but it will be sufficient to mention here two general methods of procedure:—

The operation, according to the first method, is performed by making a short semilunar incision from one side of the finger to the other, on its dorsal surface, the convexity pointing towards the nail. This flap is then drawn back, the knife is carried

Fig. 39.



through the articulation dividing the ligaments, and afterwards carried forwards in close contact with the palmar aspect of the

[1] Science and Art of Surgery, Phila., 1878, vol. i. p. 86.

bone, thus forming the anterior flap. It is desirable, not only in this operation, but in all amputations of the finger in which anterior and posterior flaps are employed, that the anterior flap should be sufficiently large, that after the healing of the amputation wound the cicatricial line may be on the posterior surface of the stump, instead of being on its tip or anterior aspect. It is not commonly necessary after amputation of the fingers to resort to ligation of the arteries, as the hemorrhage may be usually controlled by momentary pressure prior to closing the flaps, or even a trivial bleeding may be entirely disregarded while the surgeon proceeds to introduce the iron wire sutures and apply a bandage which will prevent the further loss of blood. This method is represented in Fig. 39, and the operation by transfixion is illustrated in Fig. 40.

Fig. 40.

In the latter method the flap on the palmar surface of the finger is conveniently made by introducing the point of the

scalpel on either side of the finger directly in front of the articulation, and then carrying the knife forward close to the bone. The only difficulty in this procedure is to determine the locality of the joint. The anterior flap having been made, the finger should be forcibly extended, that the knife may be readily passed through the joint severing the ligaments and cutting the posterior flap.

Amputation between the proximal and second phalanges may be performed by either of these methods, and when this operation involves the index finger, a very useful stump may be thus formed, especially for laboring subjects or those engaged in mechanical pursuits; although the hand will present a better appearance if the finger is removed at the metacarpo-phalangeal articulation. The latter fact may properly influence the action of the surgeon in all cases where the beauty of the hand may be preferred to its utility. An amputation of a finger at the middle joint except in the case of the index finger, the stump of which forms a useful opponent to the thumb, ought not to be generally practised, since no flexor tendon is attached to the proximal phalanx, the stump is apt to remain permanently extended, in which position it is frequently a source of inconvenience to its possessor, and it is always unsightly.

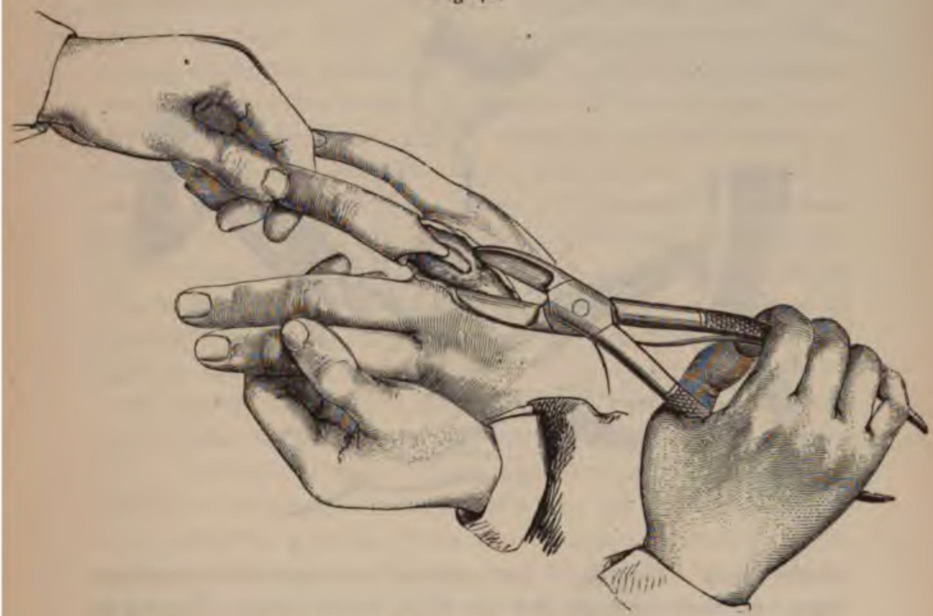
An amputation of a finger in the continuity of the second phalanx may be performed either by the circular or flap methods, the bone being divided by a sharp pair of pliers; and here the same general law which requires the surgeon to sacrifice as little as possible of a diseased or injured member is especially applicable, since by so doing he adds to both the utility and beauty of the parts without endangering in the slightest degree the life of the patient.

Amputation at the metacarpo-phalangeal articulation is frequently required, and may be performed by lateral flaps or the oval method. The lateral flap operation is illustrated in Fig. 41, and the oval method in Fig. 42.

It is necessary to determine accurately the location of the joints before beginning the operation by either method. The articulation is commonly situated in an adult about one inch

above the commissure, and it may be recognized by making strong traction on the finger and thus separating the joint. In

Fig. 41.



the performance of the operation by lateral flaps the fingers adjacent to the one which is about to be removed should be well separated by an assistant, who grasps the hand in such a manner as to put the integument on the dorsum upon the stretch. The surgeon then introduces the point of the scalpel about three-fourths of an inch above the head of the metacarpal bone, carrying it forward in such a manner as to form a semilunar incision that terminates at the middle of the palmar aspect of the member, on a level with the web of the contiguous fingers. The same process is repeated on the opposite side, the flaps are dissected up, the extensor tendon is divided, the joint opened, and disarticulation performed. The operation is now completed by the removal of the head of the metacarpal bone for the purpose of giving greater symmetry to the hand. The propriety of the latter operative procedure may be justly questioned if the

patient is a laborer or mechanic, since it will certainly increase the danger of septic infection and frequently diminish the power

Fig. 42.

of the hand. The lateral flap operation possesses this advantage over the oval method, that the flaps, when skilfully formed, fit more accurately over the end of the bone, and consequently it prevents an accumulation of blood within them.

The advantages claimed for the oval method are, that it does not wound the palm of the hand, and may be more rapidly performed. The oval method is peculiarly adapted to amputations about the hand and foot, since it leaves but a single cicatricial line. In the performance of this operation the scalpel is entered at the same point as in the last case, is carried down in a straight line on the dorsum of the finger a variable distance, and then the member is encircled by an oval sweep of the knife, which is passed directly through the upper portion of the web, transversely across the palmar aspect, and backward to the straight line on the back of the finger. Care should be taken that the incision on either side of the finger may be made on the same level, and may connect with the straight line at exactly the

same point. The oval flap is now dissected up and turned back, and the articulation opened. It may at this time be found desirable to ligate the bleeding arteries, although many surgeons prefer to postpone it until after the removal of the head of the metacarpal bone. In the case of an amputation of the middle or ring finger, the transverse incision through the metacarpal bone is most readily accomplished with the bone forceps; but if the index or little finger is to be removed, the bone should be cut obliquely from without inwards, so as to preserve as far as possible the symmetry of the hand. This may be readily done with the bone forceps or a small saw. The saw is preferable, since it cuts the bone more smoothly and without splintering or otherwise injuring it. The stump obtained by this method of procedure not only adds to the beauty of the hand, but is less liable to injury after the healing of the amputation wound.

IT MAY OCCASIONALLY HAPPEN THAT AN AMPUTATION OF ALL THE FINGERS AT THE METACARPO-PHALANGEAL JOINT MAY BECOME SIMULTANEOUSLY NECESSARY as the result of an accident. It is important before commencing this or any other surgical operation, that the surgeon should give proper attention to the anatomy of the parts. In this case, a glance at the patient's hand will satisfy him that the distal extremities of the metacarpal bones are not all on the same level; and if he will make strong traction on each finger separately, he will thus be enabled to locate accurately each metacarpo-phalangeal articulation by the separation which occurs in it. The surgeon having determined the exact location of these joints may now proceed intelligently with the formation of the flaps. The operation is easily performed by making two flaps, one on the dorsal and the other on the palmar aspect of the hand. The operator will generally find it more convenient to make the dorsal flap first, but the site at which he will first introduce the point of the scalpel must generally depend on the hand which he is about to remove. In the removal of the fingers of the right hand the surgeon will commonly find it advantageous to introduce the point of the scalpel on the radial side of the index finger exactly opposite to the metacarpo-phalangeal joint, but in

amputating the fingers of the left hand he will find it more convenient to enter it opposite the metacarpo-phalangeal articulation on the ulnar side of the little finger. The surgeon in this method of procedure holds the patient's wrist with his left hand, while the injured fingers are managed by an assistant. Having commenced the operation opposite the metacarpo-phalangeal joint, the incision is now carried down the phalanx far enough to give sufficient length to the dorsal flap, and it is then carried transversely over the roots of the fingers about one-half or three-fourths of an inch in front of their junction with the metacarpal bones, terminating on the right hand at the same point where it is begun on the left, and *vice versa*. The dorsal flap is then turned back, the tendons and ligaments are divided, and the palmar flap is formed by cutting from above downward, and from behind forward, terminating in the hand on a line with the web of the fingers. The flap thus formed will be slightly convex in front; the appearance of the stump may be improved by removing the projecting portion of each knuckle of the metacarpal bone with the bone forceps. The after-treatment in these cases should be such as to promote rapid healing of the wound, prevent deformity, and secure symmetry of the parts. The rapid healing of wounds and the prevention of accidental wound complications will be thoroughly considered in another part of this work.

The prevention of deformity and the procurement of symme-

Fig. 43.

try may be aided by binding the hand on a splint, the ends of the fingers being separated with pledgets of lint, and care being

taken that they do not overlap. The appearance of the hand continues to improve after these operations for many months

Fig. 44.

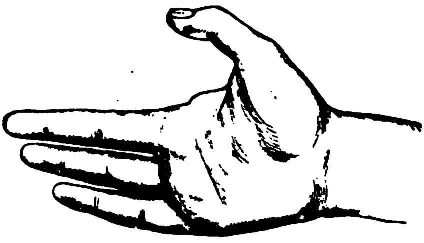
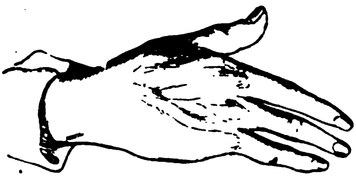


Fig. 45.



owing to the gradual atrophy of the shaft of the metacarpal bone. Figs. 43, 44, and 45 convey a very correct idea of the symmetry and general appearance of the hand after the complete recovery.

AMPUTATION OF THE THUMB AT THE DISTAL JOINT OR IN THE CONTINUITY OF THE FIRST PHALANX, may be performed in the same manner as amputation of the fingers, and consequently does not require any particular notice. It is very important in disease or injury of the thumb, *that as little as possible should be removed by amputation,* since a very short stump will serve as an opponent to the fingers. The thumb is the most important member of the hand, and, since each of its bones is provided with distinct muscles, it is possible to remove any one bone and yet leave a useful member. In those cases where the removal of both bones is *unavoiadble,* a much more sightly stump is formed by AMPUTATING AT THE CARPO-METACARPAL ARTICULATION. This operation may be performed by the oval method or with the lateral flaps. Fig. 46 shows the line of the incision,

Fig. 47 the disarticulation of the carpo-metacarpal joint, and Fig. 48 the appearance of the hand after the operation.

Fig. 46.

Fig. 47.

Fig. 48.

The amputation of the thumb by the oval method requires that the point of the scalpel should be entered about three-fourths of an inch above the carpo-metacarpal articulation, carried down in a straight line on the dorsum of the thumb a variable distance, and then the member is encircled by an oval sweep of the knife, which is passed directly through the upper portion of the web, transversely across the palmar aspect and backward to the straight line on the back of the thumb. Care should be taken that the incision on either side of the thumb may be made on the same level, and may connect with the straight line at exactly the same point. The incision having been carried down to the metacarpal bone throughout, it should now be enucleated, after which strong traction being made on it

will enable the surgeon to disarticulate the joint readily. The operation is now quickly completed by securing the bleeding arteries and closing the wound with the required number of sutures. It is quite immaterial in the performance of the operation whether the incision is made first on the inner side of the thumb, or *vice versa*, and consequently the actions of the surgeon conform to his own convenience. The amputation of the thumb at the carpo-metacarpal joint by the lateral flap method is well shown in the following figures.

Fig. 49 exhibits the inner flap and the line to be followed in making the outer one. Fig. 50 shows the completion of the

Fig. 49.

outer flap after the disarticulation of the joint. The performance of the lateral flap operation commences in this instance by

Fig. 50.

strongly abducting the thumb, then the amputating knife is placed on the web midway between the thumb and index finger, is carried upwards by a sawing motion between the first

and second metacarpal bones until it touches the base of the former, and especial care should be taken to prevent opening the carpo-metacarpal articulation of the index finger. The larger knife may now be advantageously exchanged for a narrow bladed scalpel, which can be more readily passed through the carpo-metacarpal articulation of the thumb when this member is strongly abducted. The ligaments of the joint having been thus divided the larger knife will again be found more convenient. The external flap is now quickly made by carrying the knife along, and close to the radial side of the metacarpal bone of the thumb to a point exactly opposite to that at which the operation commenced in the web between the thumb and index finger. The bleeding arteries are now secured and the wound properly closed with sutures.

THE REMOVAL OF THE WHOLE, OR A PORTION OF A METACARPAL BONE WITH THE CORRESPONDING FINGER, may be made necessary by disease or injury. *The latter is decidedly preferable, since opening a carpo-metacarpal joint may lead to troublesome complications.* The operation should be performed by making a triangular incision on the back of the hand, directly over the metacarpal bone which is to be removed, the apex being directed toward the wrist, while its base extends to the root of the finger. There should be removed only a small portion of integument in the performance of this operation. Any tendon uncovered by the removal of this portion of the integument should be cut so near to the wrist as to be out of the way in succeeding operative procedures. The most troublesome part of the operation is the separation of the metacarpal bone from its muscular and ligamentous connections. This having been accomplished the bone may be separated at the carpo-metacarpal joint, or divided obliquely in its continuity with the bone forceps. The oval method, or a modification of the same, is generally employed for amputations in the continuity of the metacarpal bones, or their disarticulations at the carpo-metacarpal joints. The

Fig. 51.

illustrations (Figs. 51, 52, and 53) give a very correct idea of these operations.

Fig. 51 indicates the lines to be followed in making the incisions in a DISARTICULATION OF THE SECOND METACARPAL BONE. Fig. 52 represents the same operation while the surgeon is still engaged in separating the bone from its muscular attachments.

Fig. 52.

Fig. 53.

Fig. 53 shows the lines to be followed in making the incisions in a disarticulation of the fifth metacarpal bone. In the removal of the second metacarpal bone the hand should be kept pronated, and the thumb and middle finger should be drawn away from the index finger by an assistant. The surgeon introduces the point of the scalpel about half an inch above the carpo-metacarpal joint, and on a line with the centre of the same which he carries downward and inward, thence around the base of the finger, cutting the web midway between the index and middle fingers, carrying the knife transversely across the palmar aspect and around the outer side on a level with the incision on the inner side, and thence upward and inward, until it intersects the first incision at or below its starting point. These incisions are now carried down to the bone, which is freed from its ligamentous and muscular connections. The prolongation of the carpal extremity of the metacarpal bone of the index finger, together with the peculiar manner in which it is wedged

between the first and third metacarpal bones, and the firmness of its articulations with the trapezium, trapezoid, and the os magnum renders the removal of the carpo-metacarpal head very difficult.

A DISARTICULATION, OR AN AMPUTATION IN THE CONTINUITY OF THE FIFTH METACARPAL BONE, may be readily accomplished by the oval method aided by a linear incision, as shown in Fig. 53. The linear incision may be made on the ulnar aspect as represented in that figure, or on the dorsum of the hand. In the performance of the former operation the hand should be kept strongly pronated, and the point of the scalpel should be introduced about half an inch above the carpo-metacarpal joint, and from here it should be carried downward in a straight line to the inner border of the metacarpo-phalangeal joint; thence obliquely forward and inward across the palmar aspect of the finger; thence through the web and afterwards obliquely backward and outward to the straight line, which it should intersect at a point exactly opposite to the end of that which crosses the palmar aspect. This operation is readily completed by carrying these incisions down to the bone, which is then easily enucleated. The following figure represents the appearance of the wound after the performance of this operation.

The hand being properly pronated and held by an assistant, the dorsal operation may be performed as follows: the point of the scalpel should be introduced about one-fourth of an inch above the carpo-metacarpal articulation of the fifth metacarpal bone, and carried downwards in a straight line to the metacarpo-phalangeal joint from whence the knife is carried around the finger in accordance with the rules already given for the performance of an amputation of a finger by the oval method at this point. The metacarpal bone is now separated from its muscular and ligamentous connections. This part of the operation should always be cautiously performed lest unnecessary injury might be done to the palm of the hand. The removal of two or more contiguous

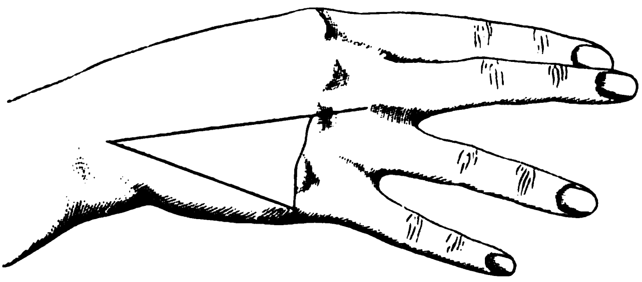
Fig. 54.

metacarpal bones with their corresponding fingers should never be regarded as a desirable operative procedure, and *the preference should always be given to* AMPUTATION IN THEIR CONTINUITY *when this is practicable.* It seems scarcely necessary to give specific rules for the performance of these disarticulations since they are rarely required, and even when necessary the formation of the flaps and other steps in the operation must depend principally on the nature of the injury or disease; however the fourth and fifth metacarpal bones may be readily removed. The hand being pronated, the point of the scalpel may be introduced opposite to the metacarpo-phalangeal articulation on the ulnar side of the little finger, or on the radial side of the ring finger midway between its web and the metacarpo-phalangeal joint; and since these points are to be connected by the first incision, the convenience of the surgeon may determine the starting point of the operation. The incision thus indicated is carried down to the bones, then a palmar incision is made by connecting the extremities of this dorsal and carrying the knife through the upper portion of the web of the ring and little fingers. Another incision, triangular in form, should be made on the back of the hand, the centre of which should be the interosseous space between the fourth and fifth metacarpal bones, while its base should rest on the dorsal incision previously mentioned, and its apex should extend about three-fourths of an inch above the carpo-metacarpal articulations of the bones involved in this operation. These incisions should be carried down to the bones and the flaps sufficiently dissected up, after which the fifth metacarpal bone is enucleated and so held by an assistant, as to no longer inconvenience the surgeon in his efforts for the removal of the fourth metacarpal bone, which may now be readily accomplished. The outlines of this operation are shown in the following illustration, Fig. 55.

Dr. Stephen Smith gives the following direction for the DISARTICULATION OF FOURTH AND FIFTH METACARPAL BONES. "Make a transverse incision a little in front of the articulations, another parallel to the axis of the metacarpal bones, upon the dorsum of the fifth, in order to cut upon that part a dorsal flap which is to

cover the whole ulnar side of the wound after the operation; the disarticulation is thus effected, and a small flap formed, which must be separated down to its base in the palm of the hand, in order to be able to raise it upon the transverse branch of the

Fig. 55.



wound. The same process is adapted to any other two metacarpal bones."[1] In connection with the amputations through the metacarpal bones Mr. Erichsen has called attention to the following important fact: "When only one finger is left, as the index or little finger, with the thumb, in cases of partial amputation of the hand after injury or for disease, the digit that remains not only becomes more mobile than formerly, but greatly increased in size and much stronger, so that its utility is materially augmented."[2]

Disarticulation of the last four Metacarpal Bones with the Preservation of the Thumb.—The operation commences by the formation of a semicircular skin flap in the palm of the hand, by an oblique crescent-shaped incision, which begins at the web of the thumb and terminates on the ulnar border of the fifth metacarpal bone at its carpo-metacarpal articulation. This flap may be readily formed by transfixion from within outward at the same points.

Fig. 56 represents the line to be followed in the formation of the palmar flap, and the relation of the parts to the same. Fig.

[1] Operative Surgery, Boston, 1879, p. 605.

[2] The Science and Art of Surgery, vol. i. p. 92, Philadelphia, 1878.

57 represents the formation of the same flap by transfixion. The palmar flap having been completed, an incision is now

Fig. 56.

Fig. 57.

made on the back of the hand commencing at the web of the thumb, and extending from this point obliquely upwards to the

Fig. 58.

Fig. 59.

upper third of the second metacarpal bone, and from thence on the same level over the last three metacarpal bones connecting

on the ulnar border of the hand with the palmar flap. Both flaps are now dissected up to the carpo-metacarpal joints, and the hand being forcibly abducted these articulations are opened from the ulnar side, including the connections between the second metacarpal bone and the trapezium. In the last part of this procedure great caution should be exercised to avoid injuring the articulation between the trapezium and the metacarpal bone of the thumb.

Fig. 58 represents the line to be followed in the formation of the dorsal flap with the relation of the parts. Fig. 59 represents the completed operation. A similar procedure may be employed in amputating in the continuity of the metacarpal bones of the fingers.

Disarticulation at the Wrist.

Amputation at the wrist certainly possesses some advantages over an operation in the continuity of the bones of the forearm; and among these may be mentioned the objection to opening the cancellous structure of a bone when it may be readily avoided, since it unquestionably occasionally lead to septic complications. Prof. S. D. Gross remarks that "disarticulation at the wrist should always be preferred to amputation of the forearm whenever it is practicable, inasmuch as the mutilated extremity affords a much longer lever, which may afterwards be used with great advantage for various purposes; at the same time it is more easily adapted to an artificial hand. I have repeatedly seen persons who, after this operation, enjoyed an amount of action in the limb that was truly astonishing, and who expressed very great satisfaction at having so good a weapon of defence in accidental pugilistic rencounters, the long stump enabling them to deal a most powerful blow."[1] There is as great a difference in the opinions of surgeons as to the best method of operative procedure at the wrist joint as in any other part of the body. Mr. Erichsen says: "The opera-

[1] System of Surgery, vol. ii. p. 1025, Phila. 1866.

tion may be performed in two ways, the chief flap being cut either from the dorsal or palmar surface. In the first case, it is best performed by *Teale's method*."[1] In the latter case he recommeds a slight modification of the same operation. Prof. Gross recommends two flaps, an anterior and posterior of equal length, and semicircular in form.

Prof. Frank H. Hamilton greatly prefers the circular method, which is also recommended by Esmacrh and Alphonse Guérin. Unquestionably good results may be obtained by either of these methods, and familiarity with all may be occasionally advantageous; but each surgeon at the commencement of his professional career should select a method which he intends to commonly practise, and never employ any other except to meet special emergencies, since by long practice he may become expert in the chosen method, which will consequently give more satisfactory results than could be otherwise obtained. The circular amputation is performed as follows: the forearm being held midway between pronation and supination, the surgeon now determines by means of the styloid processes the location of the joint, then proceeds in accordance with the rule which requires that the length of the flap should be equal to two-thirds the diameter of the limb at the point of the operation, to pass the knife with a single sweep around the extremity, cutting through the integument, which should now be raised up from the adjacent structure as far as the articulation, and turned back like a cuff by the assistant. The integument on the back of the hand will be readily dissected up, but on the palmar surface it is firmly adherent to the fascia, and the surgeon generally finds it more convenient to include everything in the flap except the tendons.

"Having turned back the integument, search must be made for the point of the internal styloid process, and the internal lateral ligament must then be divided by entering the edge of the knife below the process, and carrying it a little upward and inward. When this is accomplished the radius separates freely from the os lunare, and the disarticulation is easily and quickly effected.

[1] Loc. cit. p. 92.

"Reference has been made to the danger of entering two rows of carpal bones by approaching this articulation from the radial side. It ought to be mentioned that in the attempt to enter the wrist from the palmar surface the operator is very prone to fall above the extended end of the radius, in consequence of mistaking the latter for the carpal bones. The amputation being completed, the radial, ulnar, and interosseous arteries may require to be tied. The tendons should be cut off by a clean incision where they hang out from the sheaths, but they must not be drawn out forcibly and then divided. In closing the wound the flaps are to be approximated from the palmar to the dorsal surfaces; and now the peculiar excellence of the circular incision will become apparent as the excess of integument will form pouches on each side, over the styloid processes which will effectually prevent any protrusion of the bones."[1]

The following illustrations represent different stages of the circular amputation.

Fig. 60.

Fig. 61.

The former figure shows the appearance of the parts during the progress of the work, and the latter the completed operation.

[1] The Principles and Practice of Surgery, p. 351 *et seq.*, by F. H. Hamilton, N. Y.

Flap Amputation.

The performance of this operation commences by making two flaps, an anterior and posterior, which are semicircular in form, and of suitable size to cover the bones neatly after the disarticulation. The hand should be pronated and flexed as the first incision is made on its dorsum, commencing at the styloid process of the ulnar and extending to that of the radius, or *vice versa*. The integument should now be dissected up, turned back, and the joint opened from the dorsal surface. The division of the posterior and lateral ligaments enables the operator to flex the hand still further, after which the knife is readily carried through the articulation and a flap is formed from the palmar surface similar to that on the dorsum of the hand. The tendons should now be cut short in both these flaps, the styloid processes of both the ulna and radius should be cut off on a

Fig. 62.

level with the cartilaginous surfaces of the bones, the arteries should be secured with ligatures, the flaps closed, and the wound dressed.

Fig. 62 represents the lines to be followed in making the

flaps, and Fig. 63 shows the operation while the surgeon is engaged in disarticulating the bones. Mr. Erichsen strongly

Fig. 63.

recommends at the wrist the amputation represented by the following illustrations (Figs. 64 and 65).

Fig. 64.

The operation delineated in Fig. 64 is performed as follows: "A perfectly square flap, whose four sides are equal in length to half the circumference of the limb at the level of the wrist-joint, is raised from the back of the hand. It must consist of

skin and fat only, the extensor tendons being left on the hand. A short palmar flap, also composed of skin and fat only, and equal in length to one-quarter of the dorsal flap, is now raised. The extensor tendons may now be divided at the level of the

Fig. 65.

wrist, and the joint opened and disarticulated. Lastly both flaps being held well back, the flexor tendons are smoothly divided with a single sweep of the knife. The flaps must be brought accurately together. . . . By this method the dorsal flap is somewhat long and thin, and is consequently liable to slough unless it is very carefully raised, care being taken not to turn the edge of the knife to the flap, but to keep it constantly directed towards the parts to be removed. In amputation by the *long palmar flap*, the operation has been performed, either by cutting the flap from within outward after opening the wrist-joint, or by shaping the flap from the palm first and disarticulating afterwards. The former method is objectionable as the prominence of the pisiform bone and the hook of the unciform on the inner side, renders its performance extremely difficult. In the latter method (Fig. 65), a large flap, almost square in shape, but having its angles rounded off, is marked out in the palm by an incision, commencing at one styloid process and terminating at the other. The flap should extend as far as the transverse fold in the palm opposite the heads of the metacarpal bones. The flap having been thus marked out it is carefully raised over the palm, and is made to include everything down to the flexor tendons. When the palmar flap has been

raised to the level of the wrist-joint, a curved incision, with its convexity slightly downward, is made, so as to connect the two extremities of the previous incisions. The joint is now opened and the ligaments divided. The hand is attached now only by the flexor tendons, which may be divided by a single sweep of the knife—the palmar flap being carefully held out of the way. The palmar flap will be found usually to contain the median and ulnar nerves, and the superficial palmar arch, with portions of the muscles of the thumb and little finger. It is better to cut the two nerves short in order to prevent their implication in the cicatrix."[1]

Dabrueil's Amputation at the Wrist.

The single semilunar flap of this operation is taken from the metacarpal region of the thumb. The base of the flap is formed from the integument over one-third of the carpal circumference on the radial side of the hand, and its apex is situated at the first metacarpo-phalangeal articulation. In the performance of this operation the surgeon should commence by marking out the flap, which is then formed by introducing the point of the scalpel at either end of the semicircular line and drawing it to the other, thus cutting through the integument, which is now

Fig. 66.

Fig. 67.

dissected up and turned back, after which the incision is quickly completed by a half circular sweep of the knife around the re-

[1] Science and Art of Surgery, vol. i. p. 92 *et seq.*, by Erichsen, Philadelphia 1878.

maining two-thirds of the carpal circumference on the ulnar side of the hand. The integument of the entire flap should now be drawn upwards and turned back, and the wrist-joint opened on the dorsal surface. The disarticulation will be greatly aided if the hand is strongly flexed. Finally both the ulnar and radial styloid processess should be removed, the bleeding arteries ligated and the wound properly closed. The line to be followed in the performance of this amputation and also the appearance of the completed operation, are well represented in the preceding illustrations (Figs. 66 and 67).

Amputation of the Forearm.

The forearm may be removed in any portion of its continuity, but it is desirable, for reasons which have already been mentioned, to leave as long a stump as possible; and the fact should not be overlooked, that the upper extremities possess a higher vitality than the lower limbs, and consequently the surgeon may disregard traumatisms involving the stump in operations on the former, which on the latter would require that the amputation should be made above them. This operation may be well performed by the convex or rectangular flaps, according to the fancy of the operator, but these can only include integument and subcutaneous fascia in the lower two-thirds of the forearm, and for this reason, as well as others, I commonly employ the circular method. The circular amputation is here quickly performed as follows: The limb being held midway between pronation and supination, the surgeon assuming that position which enables him to perform the various parts of the operation with the greatest facility, passes the short amputating knife under and well over the limb, the point of this instrument being inclined downwards at an angle of forty-five degrees or more; the cutting edge, as near the shank as possible, is now brought in contact with the integument, which the operator now incises together with the subcutaneous fascia by a single sweep; the assistant immediately seizes the skin above the circular incision, which in most cases he readily retracts sufficiently to

give the required length of flap, but if he fails it must be dissected up and turned back like a cuff, after which the incision through the muscles should be made in strict accordance with the instructions given for incising the skin and subcutaneous fascia. The point at which the first incision is made depends on the disease or traumatism, but the second is determined by the required length to cover the parts.

The general rule applicable to all cases of amputation requires that the aggregate length of the flaps should be one-third greater than the diameter of the limb at the point of the operation; consequently, if the antero-posterior diameter of the forearm is two inches, then the integument and fascia should be dissected up one inch and one-third, at which point the muscles should be incised, thus giving the necessary length of flap. The interosseous membrane is now divided by passing a scalpal between the bones, the saw is then properly applied, and worked in such a manner as to sever both bones simultaneously, in order to avoid as far as possible the inconveniences which are otherwise liable to arise. The ulnar, radial, and interosseous arteries are commonly the only vessels which require ligation. The integument of the anterior surface is now brought in contact with the posterior surface. It will now be observed that there remain small pockets at the internal and external angles of the amputation wound. These pockets are certainly the objectionable features of the circular amputation when the wound is treated according to Lister's method; since they are quickly filled with the wound-fluids, which prevent the complete approximation of the parts. In order to prevent this objectionable feature in the application of the antiseptic treatment, I have sometimes rounded off the angles, thus converting the circular into the antero-posterior flap method. The beautifying power of nature is fully shown in the changes which are effected in the stump left by the circular operation. The unsightliness quickly disappears, and no more beautiful or serviceable stump can be secured by any other operative procedure.

Flap Amputation of the Forearm.

This operation is given the preference over the circular by many eminent surgeons, and it cannot be denied that equally good results may be obtained by it. The musculo-cutaneous flap operation may be employed in the upper third of the forearm, but in the lower two-thirds the flaps covering the bones are preferably formed from the integument and the subcutaneous fascia, thus avoiding the tendons. This operation may be performed either by single or double flaps, the former being generally cut from the palmar surface, and the latter from both the palmar and dorsal. The double flap amputation is generally employed, and it is also recommended to make the dorsal flap a little longer than the palmar, so that the cicatrix may not be formed over the ends of the bones. Both flaps may be formed by cutting from without inward, or from within outward; and some surgeons prefer to form one flap by cutting from without inward, and the other by transfixion. The chief objection to transfixion is the protrusion of a mass of muscles and tendons beyond the integument, which the operator is subsequently compelled to remove. The nerves found protruding from recently cut flaps in any part of the body ought always to be drawn forwards and cut short, lest they become involved in the cicatrix and give rise to much subsequent pain and inconvenience. An inexperienced operator should always take the precaution to outline the principal amputations before making an incision. These lines which are to be closely followed in the formation of the flaps may be conveniently made by dipping the tip of a penholder or the end of a glass rod in the tincture of iodine, which then being drawn over the skin leaves a sufficiently distinct line.

This operation, according to Mr. Erichsen, is performed as follows: "The surgeon, standing, so as to take the flaps in his left hand, and holding the arm with its dorsal surface upwards, enters the knife at the palmar edge of the bone furthest from him. He then marks out a flap from the surface, equal in length to two-thirds of the antero-posterior diameter of the limb at the point where it is intended to saw the bones. The flap must be sufficiently broad and rounded at its corners. After raising this,

taking only the skin and fat, a flap similar in shape, but half the length, may be raised from the palmar surface in the same way. The knife is now firmly swept round the bones at the level of the angle of the flaps, so as to divide the muscles circularly at this point (Fig. 68). The soft parts are now to be retracted

Fig. 68.

from the bones by a process of careful dissection, for a distance of from three-quarters of an inch to one inch, and the bones cleaned and sawn at this point. The result is, that the bones are buried in the muscles, and over all lie the light skin flaps, free from any tension or tendency to displacement. There will be a dependent opening for the exit of discharges, and, when healed, the cicatrix will be well to the palmar aspect of the bones, and consequently free from pressure. It may be found, in retracting the muscles from the bones, that the anterior interosseous artery has been cut in more than one place. This may cause some trouble in securing it. Great care should therefore be taken to avoid the accident, by keeping the edge of the knife constantly turned towards the part to be removed."[1]

Amputation at the Elbow-Joint.

An amputation through the elbow-joint possesses all the advantages and none of the disadvantages common to disarticulation in most of the other joints. The operation is easily

[1] Ibid. vol. i. p. 94.

performed, the danger attending its performance is slight, the recovery of the patient is rapid and the stump is excellent. The surgeon should determine accurately the situation of the articulation, however, before he commences the operation. This may be readily done by the aid of the numerous anatomical landmarks in this vicinity, among which may be mentioned the internal and external condyles of the humerus, the head of the radius, and the olecranon process of the ulna. The choice of the operative procedure may be commonly left to the fancy of the operator, since good results may be obtained by either the circular, single, double, or the rectangular flap methods. The integument at this point constitutes the essential material available for the construction of flaps, although on the anterior surface a musculo-cutaneous flap may be obtained. It is not a matter of any great importance whether the surgeon completes this disarticulation by dividing the tendon of the triceps, or sawing off the olecranon process. The retention of this process together with the removal of the internal condyle of the humerus gives a more rotund and even appearance to the stump, although it may increase slightly the danger of the operation.

Circular Amputation.

The following illustrations represent various steps in the performance of this operation (Figs. 69 and 70).

Fig. 69.

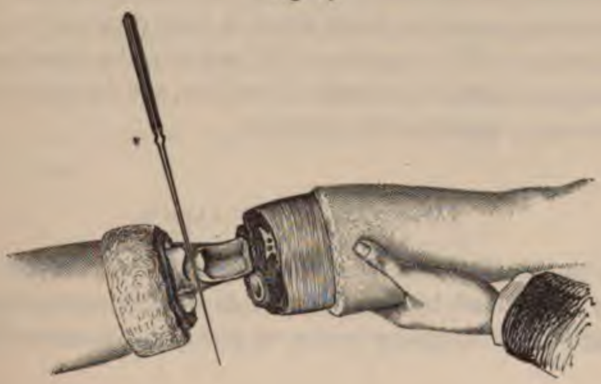


Fig. 69 delineates the appearance of the parts during the disarticulation. Fig. 70 exhibits the appearance of the stump after the completion of the operation. During the performance of the circular amputation, the forearm should be held in the position of supination, and the integument should be divided by a single circular sweep of the knife at the *proper distance* below the condyles of the humerus, which must vary in accordance with the varying diameters of the forearm; but it may be roughly stated to be about two or three inches in adults. The skin flaps should then be drawn back by an assistant, as far as to uncover the parts beneath it to the joint, or else it must be dissected up and turned back as represented in Figure 69. The forearm should now be fully extended and the joint widely opened by a transverse incision on the anterior surface. The extenal lateral ligament should be next divided by an incision above the head of the radius, and the internal lateral ligament just below the internal condyle. One assistant should now make the requisite traction on the forearm, while another steadies the arm, the effect of which will be to open widely the joint and bring down the upper border of the olecranon so as to enable the surgeon to pass the knife above it, thus dividing the tendon of the triceps. The ligation of the arteries, the introduction of the drainage tube, the closure of the flaps, and the application of the dressing completes the operation.

Fig. 70.

Double Flap Amputation.

The double, flap antero-posterior amputation may be conveniently performed by cutting both flaps from without inward, although some surgeons prefer to make the anterior flap by

transfixion. The posterior flap at this point is necessarily formed wholly from the integument, while the anterior may include the muscles or not, according to the fancy of the surgeon. It is here customary and probably advantageous to make the anterior flap somewhat longer than the posterior. The forearm being held in a supinated and slightly flexed position, the surgeon commences an incision about three-fourths of an inch below the internal condyle, and terminates it at the same distance from the external condyle, or *vice versa*. Having carried the knife around a semicircle in making this incision, thus cutting a semilunar flap on the anterior surface of the forearm, the size of which must correspond to the diameter of the limb at this point, and the proposed dimensions of the posterior flap, he may now dissect it up. The assistant may now flex the forearm, and otherwise change its position in order to assist the operator as much as possible in the formation of the posterior flap, the angles of which must intersect the angles of the anterior flap, while the incision on the posterior surface forms likewise a portion of a circle. The dimensions of this flap must correspond to the diameter of the limb, and the size of the anterior flap, which may be either large or small. The posterior flap should be next dissected up, after which the surgeon should proceed to open the joint on the anterior surface, and then divide the external lateral ligament by an incision above the head of the radius and the internal lateral ligament just below the internal condyle of the humerus. The division of these ligaments having been made, strong traction properly applied will now open the joint, and enable the surgeon to pass the knife above the olecranon process, and thus divide the tendon of the triceps. The removal of the inner trochlear will improve the shape of the stump, and on this basis may be recommended.

The Single Flap Operation.

This may be occasionally advantageously employed in amputation at the elbow-joint, when the character of the traumatism

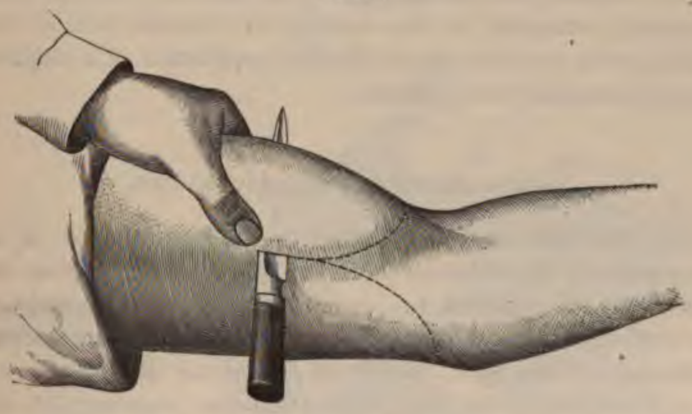
precludes the possibility of resorting to the performance of the circular or double flap operations. It is thought, however, that this operation possesses little in itself to recommend it, and, since the details of the operative procedure possess so much similarity to those of the double flap operation there is certainly no necessity for a description of it here.

AMPUTATION OF THE ARM.

Amputation of the arm may be readily performed in any portion of its continuity by the circular or flap methods; but the *general law demands that* as little should be sacrificed as possible. It is especially important, however, that the surgeon should bear in mind the fact, that when an amputation is performed above the middle of the humerus it will be followed by a marked retraction of the muscles of the flaps, and may thus uncover the bone. The explanation of this is found in the fact, that the most of the muscles embracing the humerus at this point take their origin from the thorax, shoulder, and back, and they have few or no attachments to the bone in this portion of the limb. In the performance of amputation in this portion of the limb by the musculo-cutaneous flap method, the length of the flaps must have especial reference to this probable retraction after the completion of the operation. A single bone, evenly and well padded with muscles, presents a strong temptation for the performance of the musculo-cutaneous flap amputations, since the flaps can be made so quickly and neatly by transfixion, and while the resulting well-rounded and symmetrical stump is in itself worthy of admiration. There is even danger under these circumstances that the surgeon, while contemplating an easy and brilliant operation, *may possibly forget that he ought to save as much as possible of the patient's limb.* Prof. Christopher Heath remarks that "the *circular amputation* demands for its proper performance a perfectly sound condition of the skin from two to three inches below the point at which it is intended to saw the bone; hence in cases of injury it becomes necessary either to go very high up, thus leaving a very short stump, or

to modify the operation by turning back flaps of the skin, shaped as circumstances may dictate, and dividing the remaining structures circularly."[1] The principle expressed in the above quotation is equally applicable to amputations in other parts of the body, and may be justly regarded as constituting one of the general laws of amputations. The circular amputation may be readily performed in any portion of the arm, although most surgeons prefer the easier operation by double flaps, while the performance by either method is so simple as scarcely to require a description. The performance of the double flap amputation is most rapidly accomplished by transfixion, although the flap may be very well cut from without inward; and an excellent covering for the bone may be obtained by either the lateral or the antero-posterior flaps. The following illustration, Fig. 71, represents the performance of the antero-posterior flap amputation by transfixion.

Fig. 71.



The surgeon having assumed a position which enables him to perform every part of the operation with greatest readiness, should now cause an assistant to hold the arm away from the body, when he grasps the soft parts over the anterior surface of the limb between the thumb and fingers of the left hand, and

[1] Operative Surgery, p. 97, Phila., 1878.

then entering the point of the knife just below the thumb, passes it in front of the humerus depressing the point as soon as it passes the bone and approaches the operator's fingers. The knife is now carried downwards two or three inches by a sawing movement, thus giving the flaps the proper length, care being taken to cut the skin longer than the muscles. Drawing this flap upward with the left hand, the operator passes the knife behind the bone, and then cuts downward, being careful to leave the integument sufficiently long to cover the muscular portion of the flap. The posterior flap ought to be somewhat longer than the anterior, while the aggregate length of both flaps should be one-third greater than the diameter of the limb. Both flaps are retracted, and the knife is carried around the bone thus clearing it of the soft parts, after which the saw is placed in position and drawn from heel to point, by which movement the bone is quickly divided; but the operator should be careful not to splinter it or lacerate its covering. The ligation of the arteries, the shortening of the nerves to avoid their becoming entangled in the cicatrix, the introduction of the drainage tube and the sutures, and the application of a suitable dressing complete the operation.

Amputation at the Shoulder-Joint.

The chief difficulty encountered in the performance of an amputation at the shoulder-joint has generally arisen from the inability of the assistant to properly control the hemorrhage, but with the improved methods now employed for the accomplishment of this object, there is no longer the slightest reason why a surgeon, aided by properly qualified assistants, should consider this operation more difficult of execution than an amputation of the forearm. The hemorrhage may be effectually controlled by compressing the subclavian artery as it passes over the first rib, or if the assistants are thoroughly reliable, digital compression as represented in the following illustrations may be substituted for the former.

Fig. 72 represents the oval amputation at the left shoulder-

joint, axillary artery held by an assistant. Fig. 73 represents a flap amputation at the right shoulder-joint; deltoid flap reflected;

Fig. 72.

Fig. 73.

capsule opened, and the surgeon now engaged in the formation of an axillary flap; assistant grasping the vessels behind the

knife before they are divided in the completion of the flap. There are other cicumstances, however, where it may be safer

Fig. 74.

and more convenient for the surgeon to employ Esmarch's India-rubber compressor.

The application of this instrument is shown in Figs. 10, 11, and 74. In the latter figure, prior to the application of Esmarch's tourniquet, an elastic bandage has been applied to the extremity. It has been suggested that prior to the application of this tourniquet, there should be placed in the hollow above the clavicle, a large conical pad, so as to compress the subclavian artery. The compressor is then carried under the axilla and crossed over the shoulder in such a manner as to hold firmly the conical pad in its place. The application of this instrument requires but little care, although its management becomes somewhat difficult after the disarticulation of the arm, unless it has been applied sufficiently high up, so as to embrace the scapula. The application having been accomplished, it may be retained in its place by a clasp, as represented in Fig. 11, or by an assistant, as shown in Figs. 10 and 74. Prof. S. D. Gross remarks that, "Amputation at the shoulder-joint is one of the most easy operations in surgery. Richerand long ago remarked that it might be performed with the same celerity with which an adroit carver separates the wing of a partridge, and nothing is more true, although I have occasionally seen a case in which the surgeon consumed time enough not only to cut up the whole bird, but also to devour it."[1] This operation may be effected in various ways, but it is most commonly performed by Baron Larrey's oval method, or by the flap process. Mr. Spence has suggested a modification of the oval method which may be advantageously employed in some cases of gunshot wounds involving the upper portion of the humerus, and Prof. Esmarch has described a circular operation with a vertical division of the soft parts. During the performance of this operation without regard to the method employed, the head and chest of the patient should be well elevated, the side on which the amputation is to be performed should be brought well over the edge of the operating table, and the arm should be drawn from the

[1] System of Surgery, vol. ii. p. 1028. Phila. 1866.

body by an assistant, so that the operator may have the greatest possible freedom of movement.

Oval Amputation at the Shoulder-joint.

The oval method in the majority of cases is still regarded as preferable to all others. The operation commences by the formation of a vertical incision on the external surface of the shoulder, which extends downwards from the edge of the acromion process to a point one inch or more below the head of the humerus, by which the integument and muscles are divided down to the bones. The operator now makes two lateral

Fig. 75.

oblique incisions; one begins on the anterior aspect of the shoulder in the lower portion of the vertical incision, and termi-

nates on the anterior border of the axilla; the other commences on the posterior aspect of the shoulder exactly opposite to the former, and terminates at the posterior border of the axilla. These respective incisions are carried down to the bone, and the flaps are drawn upwards by an assistant, when the operator divides the upper half of the capsular ligament, and then rotating the head of the humerus in the socket, he divides the ligaments in the posterior region and afterwards those in the anterior. The surgeon's knife may now be passed behind the head of the humerus, and the remaining soft parts be cut by a single stroke, or, should it be considered desirable, the artery may be ligated before the section is made. The illustrations (Figs. 75 and 76) afford a very correct idea of the various steps in the performance of the oval operation.

Fig. 76.

Fig. 75 shows the outlines to be followed in the formation of the vertical and lateral incisions. Fig. 76 represents the division of the soft parts in the axilla. The wound resulting from this

operation is almost perfectly oval, and although the operative procedure described here is probably as convenient and advantageous as any, nevertheless there are many variations in the performance of the same. Instead of forming the flaps as here directed, they may be conveniently made by transfixion; after which the operator may open the joint as previously directed, or the head of the humerus may be dissected from its cavity with the knife held vertically, first on one side and then on the other. The disarticulation having been completed, the remaining soft parts in the axilla may be divided by a single sweep of the knife, or should the operator prefer it, he may ligate the artery and then make the division.

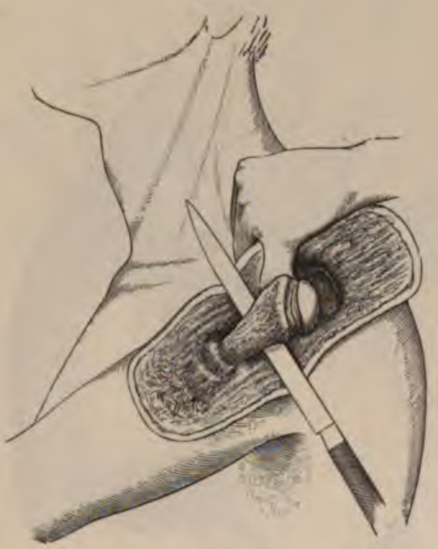
Flap Amputation at the Shoulder-Joint.

Figure 74 represents the lines to be followed in the performance of this operation, as well as a position in which the patient may be advantageously placed. In this figure the patient is represented as lying partly on the sound side, near the edge of the table, with the head and chest elevated. The nearer the patient's position approaches the sitting posture, the more convenient it is for the operator, but the danger from the anæsthetic is greater. There is formed in this operation from the soft parts covering the external surface of the shoulder a large flap which extends downwards from the coracoid and acromion processes to the insertion of the deltoid muscle into the humerus. The shape of this flap is generally the same with the exception of the lower border, which may resemble the segment of a circle, or the side of a quadrangle with slightly rounded corners. This flap may be made by transfixion or by cutting from without inward. Mr. Erichsen recommends that, "the knife, instead of being entered by a puncture should make a cross-cut about an inch in extent, at the point at which transfixion is to be made, so as to prevent that jagging of the integuments by the heel of the instrument which would otherwise occur."[1] The operator having assumed that position, which enables him to perform

[1] Loc. cit. vol. i. p. 96.

this operation with the greatest facility, now introduces the point of the knife, if the operation be on the right side about an inch in front of the acromion, or midway between the acromion and coracoid processes, which is then carried directly across the joint and capsule, making its exit at the posterior border of the axilla. If the operation be on the left side, the point of the knife must be entered well behind the spine of the scapula, at the posterior border of the axilla, carried across the anterior aspect of the joint, and brought out to the outer side of the coracoid process. In either case the parts having been transfixed, the flap is cut with a single sweep of the knife downwards, and immediately drawn upwards by an assistant, when the outer aspect of the joint will be found fully exposed. The outer portion of the capsule is now opened, and the attachment of the

Fig. 77.



muscles to the tuberosity divided by a semicircular sweep of the knife above the anatomical neck of the humerus; after which the assistant should cause the head of this bone to rotate in its socket, in order that the operator may be better enabled to

sever the remaining portions of the capsule without bringing the edge of the knife into dangerous proximity to the large vessels. Having completed the disarticulation, the operator carries the patient's arm across the chest; draws towards him the head of the humerus with his left hand, and then passing behind it the knife which he holds in his right hand, he carries it downward close to the bone about two inches and a half below the axillary fold; and then turns its edge inward towards the thorax; divides quickly the remaining soft parts which contain the large vessels and nerves. In those cases where the compress placed on the subclavian artery does not fully control the hemorrhage, the assistant should seize the artery in the wound above the knife, and compress it between the thumb and fingers against the skin, or the surgeon may ligate the artery before completing the operation.

Fig. 78.

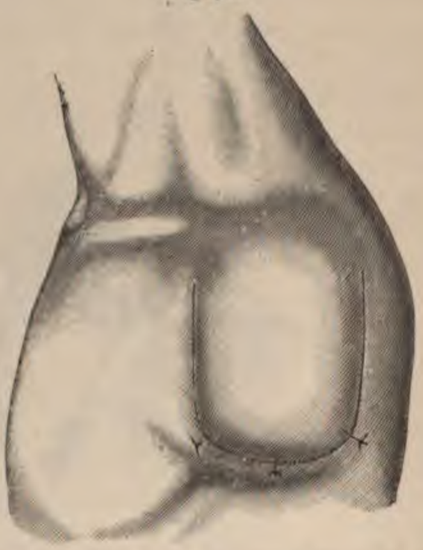
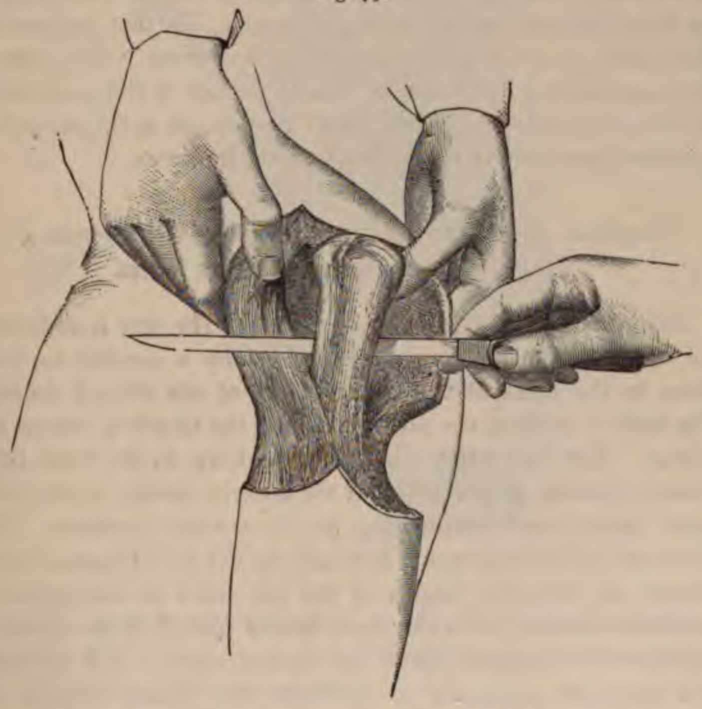


Figure 77 represents the formation of the second flap on the inner side of the arm. Figure 78 shows the appearance of the stump after an amputation at the shoulder-joint by the flap method.

Spence's Modification of the Flap Amputation at the Shoulder-Joint.

This operation, which is especially applicable in cases of comminution of the upper end of the humerus, is thus tersely described by Mr. Erichsen: "It consists in carrying the vertical incision further forward, and commencing it just externally to, and below, the tip of the coracoid process, as in excision of the shoulder-joint. The incision ought to expose the tendon of the long head of the biceps lying parallel to it and at its bottom. This may be turned on one side, and the joint opened and ex-

Fig. 79.



amined, and if, from the state of the parts, it be still considered necessary to amputate, the operation is completed by making an oval incision through the skin from the end of the original

cut, taking care not to go so deeply on the inner side as to wound the vessels. The outer flap is then dissected up, so as to enable the surgeon to get his knife internal to the head of the bone, between it and the axillary artery."[1] (Fig. 79.)

Amputation at the Shoulder by Spence's Method.

The assistant follows the knife with his hands and grasps the vessels, and the operation is finished by dividing the tissues left uncut at the inner side. In those cases in which this operation is performed for disease, especially for tumor of the humerus, by which the soft parts are thinned or condensed, it may be conveniently done by making the anterior flap by dissecting it up from without inward, using, of course, for this purpose, a short knife; a broad bistoury is most convenient. The joint is then opened and the posterior flap is formed in the usual way. In this way I have easily performed amputation at the shoulder-joint for large tumors of the head of the humerus.

Circular Amputation at the Shoulder-Joint with a Vertical Division of the Soft Parts.

This operation is performed as follows: The arm is abducted, the whole of the soft parts are divided by a circular incision down to the bone at the lower border of the deltoid muscle. The bone is sawn at the same level, and the bleeding vessels are ligated. The soft parts are now split down to the bone by a vertical incision, commencing at the anterior border of the acromion process and terminating at the circular incision. The distal end of the humerus is now held by the aid of strong bone-forceps, or with the fingers of the left hand of the operator, whilst an assistant, with the sharp hooks placed in the borders of the vertical incision draws the wound apart. The operator now proceeds cautiously to enucleate the bone, keeping the edge of the knife on it, or he may prefer in certain cases to

[1] Ibid. vol. i. p. 99.

separate the periosteum with the periosteal knife, lest by an accidental slip of the scalpel he might cause a troublesome hemorrhage. The capsular and other ligaments of the joint are readily brought into a position to be safely divided by simply rotating the head of the humerus, while this part of the operation is being performed. The following illustrations afford an excellent idea of this amputation.

Fig. 80.

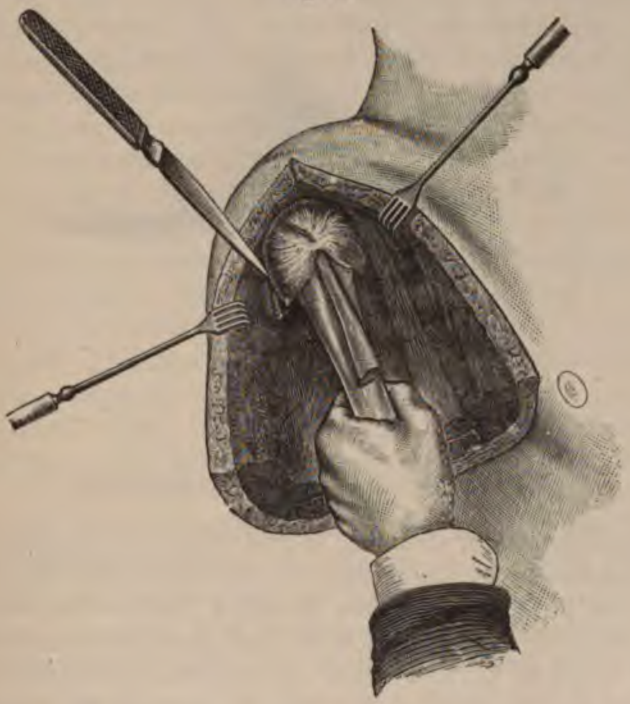
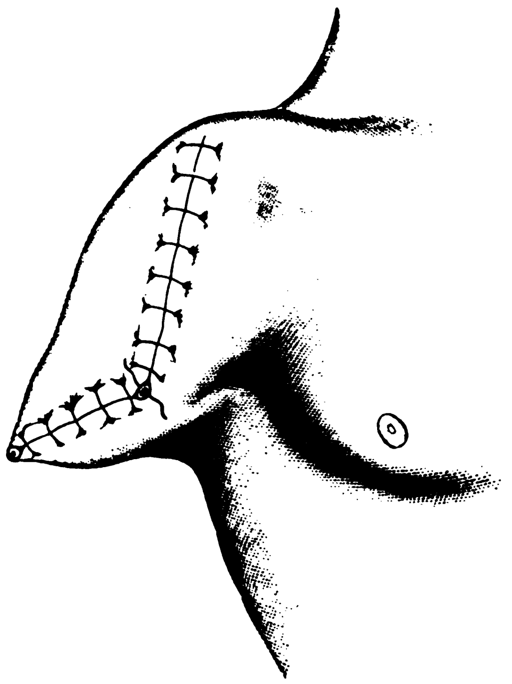


Fig. 80 represents the surgeon in the act of disarticulating the bone, and Fig. 81 shows the appearance of the stump after the completion of the operation.

Fig. 81.



Amputation above the Shoulder-Joint.

This amputation, according to Prof. Frank H. Hamilton, was first performed by Cummings in 1808, and since that time, but prior to 1872, he says the operation had been made at the scapulo-clavicular articulation, or through some portion of the clavicle, about fourteen times. Among those who have performed the operation we are able to mention the following names: Goetani Bey, Mr. Fergusson, Drs. George McClellan, Mussy, Gilbert, and Hamilton. The statistics and reports of this operation are very favorable, and Prof. Hamilton remarks that, " with the exception of Mr. Fergusson's case, in which he operated for a malignant disease of the scapula, I do not know of one who has died either directly or indirectly in consequence

of the operation."[1] Experience has undeniably shown that this operative procedure is entirely justifiable in many cases of disease and injury involving the scapula and its articulating bones. The chief difficulty to be apprehended in the performance of this operation, as well as in amputation at the shoulder-joint, comes from neglect or inability of the assistant to properly control the hemorrhage. Prof. Hamilton remarks, that during the performance of his operation the hemorrhage was completely controlled by digital compression made on the subclavian artery above the clavicle. The means here employed or some modification of digital compression will generally be found sufficient, although in exceptional cases it may be well to secure the subclavian artery, especially if the tumor necessitating the operation is very bulky, or the assistants inexperienced and unreliable. The position of the surgeon and the patient should be such as to give the operator the greatest freedom in his movements, and to enable him to perform every part of the operation with ease and promptness. The dimensions of the flaps and the other details of the operation must be regulated by the exigencies of the case. The flaps ought to be outlined on the integument before commencing the operation. Prof. Hamilton's procedure consisted: "First, in making a large flap from the inner and upper part of the arm of about seven inches in length and four or five inches in width. The base of the flap corresponded to the axilla, and included the axillary artery, which was at once tied; second, the mass was exposed by incisions over the scapula, and the dissections were continued to its inferior and posterior margins; third, the scapula was lifted from below, and after having divided the attachment of its muscles at its bases, it was forcibly torn up until the upper margin and the glenoid cavity were reached; fourth, the dissection was continued from without until the upper margin of the scapula was laid bare and its remaining connections were severed."[2]

Prof. S. D. Gross gives the following rules for the performance of this operation: "The incisions should extend, on the one

[1] Principles and Practice of Surgery, p. 357. [2] Ibid. p. 358.

hand, from the superior angle of the scapula along the upper border of that bone; and, on the other, from the anterior surface of the clavicle, nearly as far inward as its middle, round the shoulder-joint, and thence down to the inferior extremity of the scapula, in a line with its axillary margin. The flaps thus marked out, should then be rapidly dissected up, with as much soft substance as possible, and the different muscular connections severed. The collar bone should be sawn through near its middle, but not until after the separation of the scapula, as the weight of the arm, by drawing down the shoulder, will greatly facilitate this step of the proceeding. The axillary artery should be divided last, and should instantly be tied."[1] The closure of the wound and its after-treatment may now proceed in accordance with the general rules.

Special Amputations of the Inferior Extremity.

The preliminary remarks recorded at the commencement of this chapter prior to entering on the consideration of the various amputations of the upper extremity, are generally applicable here, and therefore we shall now proceed to the contemplation of—

Amputations of the Foot.

The hand is much more frequently the seat of an injury requiring its removal than the foot, and a proportionately greater exemption from injuries and operative procedures may be justly claimed for the toes compared with the fingers.

Amputation of the toes ought never to be performed in their continuity or through their phalangeal articulations, since the stumps thus left being continually impinged on by the shoe or boot could only be a more or less constant source of pain and annoyance and consequently the operation should always be made at the metatarso-phalangeal joints. The various operations performed at these joints resemble those made on the

[1] Loc. cit. vol. ii. p. 1030.

hand at the corresponding articulations. The removal of a single toe is preferably done by the oval method; since by this procedure the sole of the foot is not incised; but when all the toes are involved as may occasionally happen in cases of frost-bite and gangrene, a flap operation should be employed similar to that recommended for the amputation of the fingers at the metacarpo-phalangeal articulations. It should be remembered that the web is situated midway between the distal ends of the toes and the metatarso-phalangeal articulations, and when the incisions are made in accordance with the anatomy of the parts there is very little trouble in disarticulating these joints.

THE SIMULTANEOUS AMPUTATION OF ALL THE TOES is most advantageously performed by the means of a long and short flap, the former being cut from the sole of the foot and the latter from the dorsum. The operation should commence with an incision across the back of the foot, from one side to the other directly in front of the metatarso-phalangeal articulations. This flap is dissected up sufficiently to expose these joints, which will be more readily opened if an assistant forcibly flexes the toes, when the surgeon will divide successively with a narrow bladed scalpel the extensor tendons, and immediately pass the knife downwards through the joint. The disarticulation of these joints having been accomplished in this manner, the operation may be speedily completed by carrying a knife forward to a level with the web of the toes in order to form a sufficiently large flap from the sole of the foot to cover the amputation wound. The removal of the ends of the metatarsal bones is not only unnecessary but also disadvantageous. The ligation of the bleeding arteries, the introduction of the drainage-tube, the stitching of the plantar flap to its fellow on the dorsum of the foot, together with the application of a suitable dressing, completes this operation.

The following method of DISARTICULATING ALL THE TOES AT THE METATARSO-PHALANGEAL ARTICULATIONS seems to possess some advantages over that previously given. The surgeon having seized all the toes with his left hand bends them strongly upward, and now makes a crescent shaped incision in the furrow formed between the sole of the foot and the base of the toes.

This incision may be commenced on the inner side and directly over the centre of the metatarso-phalangeal articulation of the great toe, or at a corresponding point on the outer side of the little toe; since the point for beginning and ending this part of the operation must depend principally on the position

Fig. 82.

occupied by the operator during the operation, and the foot on which the same is performed. In either case the incision is carried obliquely downward to the furrow which has been pre-

Fig. 83.

viously described, and thence through it to the opposite point, and after the completion of this incision the plantar flap should be dissected up sufficiently to uncover the metatarso-phalangeal

joint. The toes are forcibly bent downwards, and an incision is now made on the dorsum of the foot, the extremities of which intersect with the ends of the incision which has been previously described. Both incisions are so formed as to meet between the toes in the middle of the web. The dorsal flap having been dissected up and the toes strongly flexed, their disarticulation will be easily accomplished by carrying the scalpel through the joint from above downward; thus separating only one toe at a time. It has been suggested by Esmarch, that should the flap thus formed be insufficient to cover the projecting heads of the metatarsal bones, they should be sawed off, although it is certainly very doubtful if this procedure can ever become necessary where the operation has been properly performed. The various steps of this operation are shown in the preceding illustrations (Figs. 82, 83, and 84).

Fig. 84.

Fig. 82 represents the line of the plantar incision and Fig. 83 the dorsal, while the appearance of the healed stump is shown by Fig. 84.

Amputation of the Great Toe at the Metatarso-phalangeal Articulation by the Oval Method.

The surgeon having assumed that position which enables him to perform this operation with the greatest ease and rapidity, should now seize the toe which he is about to remove between the thumb and index finger of the left hand and introduce the point of the scalpel about one inch above the metatarso-phalangeal articulation which is then carried down in a straight line over the joint on the dorsum of the toe a variable distance; and then the member is encircled by an oval sweep of the knife

which is passed directly through the upper portion of the web, transversely across the plantar aspect, and backwards to the straight line on the back of the toe. Care should be taken that the incision on either side of the toe may be made on the same level, and may connect with the straight line at exactly the same point. The oval flap should now be dissected up and turned back, and afterwards disarticulation will be readily accomplished. This method may be conveniently employed for the removal of any of the toes at the metatarso-phalangeal articulations; or even for an amputation in the continuity of the metatarsal bone, when the operation is performed near this joint; but under other circumstances the flap operation may be considered preferable. The modifications required in the oval method in order to adopt it to the removal of any one of the toes is too slight to require a description here.

The late Prof. S. D. Gross, of Philadelphia, employed a very convenient modification of the oval method in the removal of the great toe, and said: "The operation should be performed through the continuity of the metatarsal bone, and not at the metatarso-phalangeal articulation, as in this case the large head of the metatarsal bone would sadly interfere with the wearing of the boot. Two incisions are made along the dorsum of the foot, commencing at an acute angle a short distance in front of the internal cuneiform bone, passing round each side of the toe anteriorly to the joint, and terminating at the centre of the web which connects the big toe with the adjoining one. The soft structures being carefully detached, the metatarsal bone is sawn through in a sloping direction including fully one-half of its length. The sesamoid bone is removed along with the extensor tendon of the toe. The wound usually heals very promptly, and the cicatrix corresponding with the dorsum of the foot is seldom productive of inconvenience when the patient begins to walk, especially if proper attention has been paid during the operation to the preservation of the integument."[1] The appearance of the parts is

[1] System of Surgery, 4th ed., vol. ii. p. 1031.

well shown in the following illustration, Fig. 85, which represents the approximation of the wound with sutures.

The same distinguished surgeon remarks that: "When only one of the smaller toes is to be removed, the operation should be performed with oval flaps. . . . . The disjunction will be facilitated by forcibly flexing the toe. The extensor tendon should be divided above the joint. When the small toe is removed, whether alone, or along with the adjoining one, the stump will be much more seemly, as well as useful, if a small portion of the corresponding metatarsal bone be cut off, so as to give the part a sloping appearance, as in one of my cases at the Philadelphia Hospital. In the ordinary operation the stump is very angular, and the consequence is that it is constantly irritated by the pressure of the shoe."[1] The removal of a portion of the metatarsal bone of the little toe as recommended by Prof. Gross, may be entirely justifiable, *and even advantageous;* but this operative procedure in amputations of the great toe, unless made necessary by the injury, should certainly be regarded as questionable, since it is absolutely certain that by so doing the arch of the foot is deprived of a very important support, which cannot be compensated for by the greater symmetry of the resulting stump.

Fig. 85.

The Removal of the Metatarsal Bone of the Great Toe by the Flap Operation.

The operator having assumed that position which enables him to perform the various parts of the operation with the

[1] Ibid, p. 1031.

greatest ease and promptness, should now enter the point of the scalpel on the dorsum of the foot, and the interosseous space between the first and second metatarsal bones on a level with the tarso-metatarsal joint; the knife is then carried forward upon the ball of the great toe, to a point opposite to the web between the toes, it is then passed downward to the sole of the foot—having at this point formed a crescent-shaped incision—after which it is carried along the outer margin of this metatarsal bone to its articulation with the internal cuneiform; the flap thus formed is dissected up, and much care should be taken to preserve as much of the soft parts as possible. The surgeon now re-enters the knife between the first and second metatarsal bones, and cuts directly forward through the centre of the web between the great and second toes. The great toe should now be drawn away from the adjoining toe, when the surgeon with the point of his knife will be able to divide the tendinous and ligamentous fibres that constitute the key of the joint, thus enabling him to open it, after which he will readily complete the disarticulation by severing the remaining ligamentous connections, taking care not to wound the dorsal artery of the foot. Hemorrhage having been arrested, the drainage tube introduced, and the wound closed, the surgeon may then apply the usual dressing. The relation of the parts during the performance of this operation is very well shown by Fig. 86.

Fig. 86.

Amputation of the Metatarsus.

This operation may be performed by sawing through the continuity of these bones, or by disarticulating them from the

tarsus. The flaps in both operative procedures must be formed from the available dorsal and plantar soft tissues; and consequently the former will contain only integument, and the latter integument and a portion of the plantar fascia. Surgical authors have been long accustomed to designate various operations, especially on the foot, by the name of the operator who first published a detailed statement of his method of operative procedure. This time-honored and praiseworthy practice has caused some confusion among surgeons, as is shown by their varying applications of the names of Hey and Lisfranc to the operations now under consideration. Mr. Erichsen says: "The first operation—that of sawing through the metatarsus—is usually called Lisfranc's; but in reality it was practised and described by Hey long before Lisfranc's time. By 'Hey's amputation' is usually meant the disarticulation of a flap from the anterior part of the sole of the foot. But Hey describes three different amputations, only one of which corresponds to this method."[1] Christopher Heath describes Hey's operation as an amputation through the metatarsal bones, and designates the disarticulation of the metatarsus from the tarsus as Lisfranc's operation. Having made a careful examination of the writings of both authors, I am now satisfied that the application of Lisfranc's name to either of these operations is without sufficient authority. The various operations performed by Hey on the metatarsal bones would seem to have been so numerous as to leave little room for other laborers in this part of the body to manifest their genius by new operative procedures. Mr. Erichsen refers to this labor in the following words: "Thus it would appear that in the first case Hey *sawed across* the metatarsal bones after having made the flap. In the second case, he *dissected out* all the metatarsal bones, and then made a flap from the sole. In the third case, he first made the sole-flap, and then, having *dissected out* the four smaller metatarsal bones, *sawed* across the internal cuneiform; thus combining the two methods of cutting and sawing. The *whole of the metatarsal*

[1] Science and Art of Surgery, vol. i. p. 103, Phila. 1878.

bones may then be removed from the tarsal by the operation originally planned and executed by Hey. This consists in first of all making a large convex flap in the sole of the foot, one horn of which commences at the tubercle of the fifth metatarsal bone, whilst the other terminates at that of the first, or rather

Fig. 87.

Fig. 88.

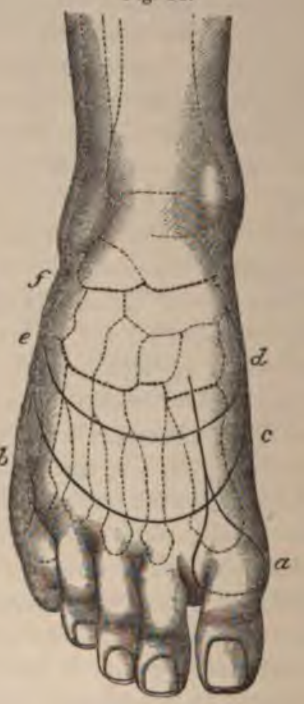


Fig. 87.—Great toe, oval amputation of first phalanx; second toe, lateral flap amputation through first phalanx; third toe, flap amputation of terminal phalanx; fourth toe, oval amputation of first phalanx.

Fig. 88.—*a*. Incision for amputation of first metatarsal bone. *b*. Incision for amputation of fifth metatarsal bone. *c*. Incision for Lisfranc's amputation. *d*. Incision for Chopart's amputation. *e*. Line of disarticulation in Lisfranc's amputation. *f*. Line of disarticulation in Chopart's amputation.

one inch in front of the tubercle of the scaphoid. A small flap is then made on the dorsum of the foot, and the articulations are exposed. These must then be opened with some care, as they are very irregular; . . . the second metatarsal bone,

especially, being sunk into a kind of pit between the inner and outer cuneiform bones, and the articulation of the fifth with the cuboid being very oblique. This operation is seldom practised, disease being rarely limited to the metatarsal bones, but usually implicating the joints as well. Their disarticulation also from the tarsus is very troublesome, on account of the irregularity of the line of articulation; hence it is better to saw through the metatarsus just in front of the tarsal articulations, than to attempt to disjoint the bones."[1]

Fig. 89.

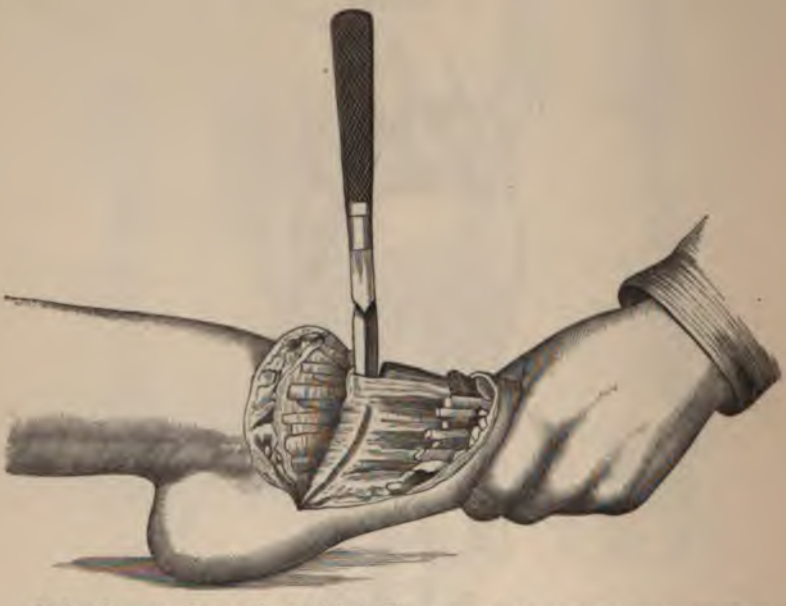
Chopart's amputation on the left foot. The sole flap formed first.

Lisfranc has remarked that these bones ought not to be sawn through their proximal half, lest the inflammation following the

[1] Ibid. p. 103.

operation might extend to the joints, and give rise to much trouble; but in these days, with our present knowledge of the origin of traumatic inflammation, and the means to prevent the same, we are enabled to entirely disregard this caution. There are cases in which we unhesitatingly now disarticulate a portion of the metatarsal bones and saw through the others, and I would, under favorable circumstances, remove the whole or a portion of the third, fourth, and fifth metatarsal bones, and attempt to

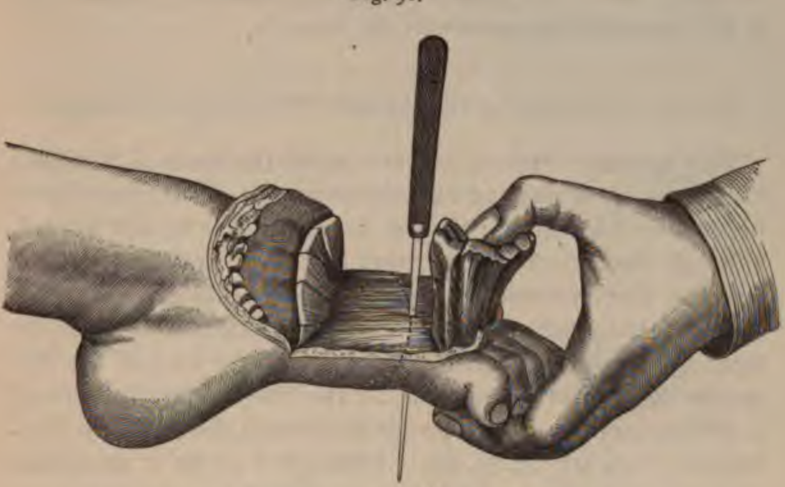
Fig. 90.



Lisfranc's amputation on the right foot. The outer and the innermost tarso-metatarsal joints opened, the knife passed between the internal cuneiform and second metatarsal bones.

preserve the first and second with their corresponding toes. The formation of the flaps in every instance must conform to the exigencies of the case, and the surgeon, after having carefully examined the lesion, can generally readily determine whether the whole, or what portion of the covering for the stump shall be taken from the sole and the dorsum of the foot. In the per-

Fig. 91.



Lisfranc's amputation. Formation of the sole flap after disarticulation.[1]

formance of Chopart's operation, or Hey's complete disarticulation at the tarso-metatarsal joints, there are two methods of procedure by which these amputations may be equally well accomplished. By the one method the dorsal flap is first formed, and the disarticulation of the bones follows next in order, while the formation of the plantar flap completes the amputation; in the other method of procedure the flap from the sole of the foot is first cut, and then that on the dorsum, while the disarticulation is the last step in the performance of the operation. The illustrations, Figs. 87, 88, 89, 90, 91, and 92, taken from Christopher

Fig. 92.

Chopart's amputation on the left foot. Opening of the transverse joint of the tarsus.

[1] Hey's complete disarticulation of the tarso-metatarsal joints.

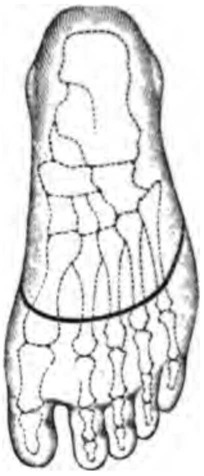
Heath's Course of Operative Surgery, represent various steps in the important operations on the foot.

AMPUTATION THROUGH THE TARSUS—CHOPART'S OPERATION.

This operation consists in removing all the bones of the tarsus except the astragalus and the calcaneum. It is a matter of little importance whether the plantar or dorsal flap be first formed, although the majority of surgeons give their preference to the former. The anatomical guides in the performance of this operation are the prominent tuberosity of the scaphoid bone on the inner side, and the external malleolus and the base of the fifth metatarsal bone on the outer side. The lines commonly followed in the performance of this operation are well shown in the illustrations, Figs. 93, 94, 95, 96. Although I prefer a somewhat

Fig. 93.

Fig. 94.



longer dorsal flap, for the reasons which are clearly stated by Prof. Heath, who regards it as a common mistake to dispense with a dorsal flap. He adds, "It will then be found, that however long the plantar flap may be, it will be inconvenient, on account of its thickness, to bring it up over the prominent as-

tragalus, whereas a dorsal flap fits neatly over and brings the cicatrix out of the line of pressure."[1] The patient's limb having been placed in a suitable position, the operator may then take that position which enables him to perform the various parts of

Fig. 95.

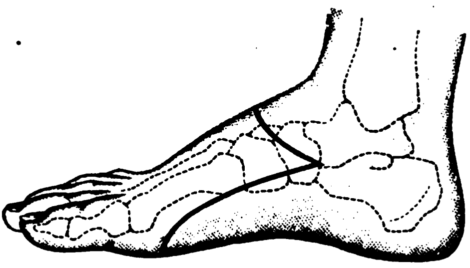
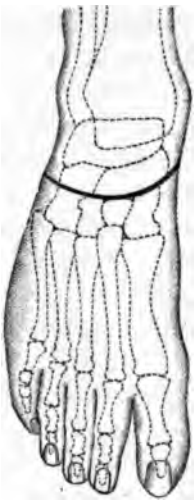


Fig. 96.



the operation with the greatest ease and rapidity. Having marked out both flaps, he then grasps the doomed toes with his left hand and introduces the point of the operating knife at the angle of the lines on the inner side of the foot, about half an inch behind the tuberosity of the scaphoid bones, and directly over the astragalo-navicular articulation, or should the circumstances of the case make it more convenient for the operator, he may commence the incision at the angle on the outer side of the foot, at a point midway between the tip of the external malleolus and the base of the fifth metatarsal bone. The surgeon may proceed from either of these angles with equal ease to the formation of either the dorsal or plantar flap. The same general rules are equally as applicable here as in other parts of the body, consequently the combined length of these flaps should

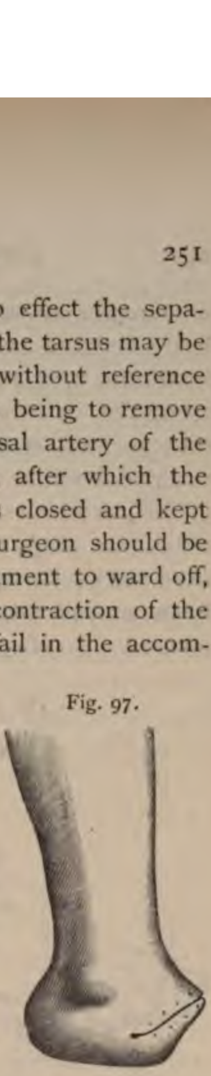
[1] A Course of Operative Surgery, page 109, Phila. 1878.

be one-half greater than the antero-posterior diameter of the foot at the point of the operation, and the longer the dorsal flap the shorter may be the plantar. This plantar flap, as will be seen by examining Fig. 95, may commence by an incision at the angle on the inner side of the foot, which has been previously described, and extend downward and forward along the lower border of the first metatarsal bone to the head of the same, thence curving across the sole of the foot over the heads of the metatarsal bones, as shown by Fig. 94, until it reaches the head of the fifth metatarsal bone, and along the lower border of this bone, as represented in Fig. 93, to the angle on the outer side of the foot. This incision having been carried down to the bones, the flap may then be dissected up, care being taken that all the soft tissues of the sole of the foot are raised with it.

In the formation of the dorsal flap, the operator's knife is made to describe a greater or less curve according to the fancy of the surgeon; but an excellent idea of the same may be obtained by examining Fig. 96. This incision having been completed, the flap is then dissected up, and freed from any tendons which it may happen to contain. Both the dorsal and plantar flaps are drawn back by an assistant, and kept out of the surgeon's way. The heel being now firmly supported on the operating table, or by an assistant, the surgeon may make firm downward pressure on the anterior portion of the foot with his left hand, which will enable him to pass the knife, which he holds in his right hand more readily through the articulation from the dorsum to the sole of the foot; but care should be taken at this stage of the operation that the edge of the knife be not inclined too much backward; lest it slip over the astragalus and open the ankle-joint; or too far forward, lest it pass between the scaphoid and the cuneiform. Mr. Erichsen has recommended that after disarticulation has been accomplished, the projecting head of the astragalus and the articular surface of the os calcis should be sawn off; but while there is no especial objection to this procedure it is certainly unnecessary in the majority of cases. It not unfrequently happens that a firm anchylosis is found to involve this articulation; and in this

case the use of the saw may be required to effect the separation of the anterior part of the foot. Here the tarsus may be treated as a whole, and its division effected without reference to articulations, the first care of the surgeon being to remove every part of the diseased bone. The dorsal artery of the foot and the two plantars require ligation, after which the drainage-tube should be introduced, the flaps closed and kept in apposition by the metallic sutures. The surgeon should be assiduous during the whole of the after-treatment to ward off, if possible, the evils which arise from the contraction of the tendo Achillis; and should other measures fail in the accomplishment of this object he ought promptly to divide this tendon. The importance of preventing this unfortunate complication cannot be well overrated; since the drawing up of the heel causes the stump to point downward, and throws the weight of the patient in walking on the cicatrix; but as this condition is generally avoidable, and always *amenable to treatment*, it ought not to militate seriously against the operation. The results of this operation are commonly very favorable, and a properly constructed foot enables the patient to walk with very little appearance of lameness. Fig. 97 represents the appearance of the stump after the performance of Chopart's operation.

Fig. 97.

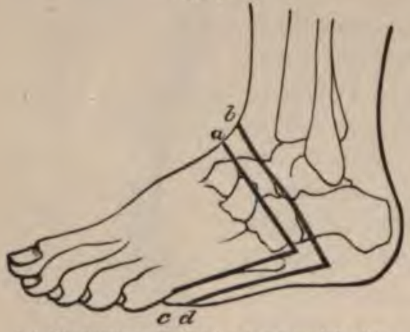


Hancock's Modification of Chopart's Operation.

Mr. Hancock introduces his modification of this amputation by saying that: "The principle objection to Chopart's amputation, however, arises from the sacrifice of the scaphoid bone and the calcaneo-scaphoid ligament, and the consequent destruction of the ball and socket astragalo-scaphoid joint, and support of the head of the astragalus, to which the rolling and twisting of the stump and retraction of the heel are mainly due. A care-

ful examination of the recorded cases of Chopart's amputation has convinced me that in a very large majority the scaphoid bone has been removed, and the support of the head of the astragalus destroyed without the slightest necessity, and from this, as well as from experience of several cases in my own practice, I would venture to urge that there are very few cases, indeed, to which Chopart's amputation can be applied in which either the whole of the scaphoid and cuboid bones, or a sufficient portion thereof, for the preservation of the calcaneo-scaphoid ligament and attachment of the tibialis posticus, may not be insured. To effect this I have for several years past substituted the following for that of Chopart. I feel for the prominence of the base of the fifth metatarsal bone, and carry an incision through the soft parts, commencing at the junction of the outer border of the foot with the sole, directly across the dorsum of the foot, from without inward to where the inner border of the foot joins the sole in that direction. Arrived at this joint, I turn my knife with its flat towards the bones, and its sharp edge forward, well into the root of the toes, complete the lower flap. The dorsal incision passes over the dorsum of the cuboid about its middle, over the dorsum of the external cuneiform at about its anterior third, and falls upon the joint between the scaphoid and two internal cuneiform bones. By depressing the front of the foot the scapho-cuneiform joints readily open, and if sound I complete the operation by sawing the cuboid across on a level with the most prominent portion of the scaphoid; if, on the contrary, the scapho-cuneiform articulations show signs of disease, I remove the articulating surface of the scaphoid, with a relative amount of the cuboid, and, after securing the vessels complete the operation by subcuta-

Fig. 98.



b d, Chopart's operation; *a c*, my modification.

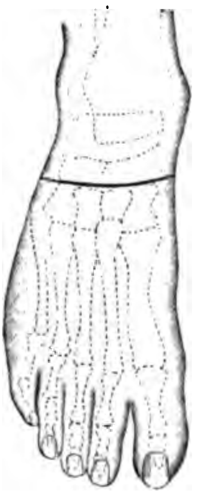
neous section of the tendo Achillis. The annexed diagram (Fig. 98) shows the lines of incision in Chopart's operation and my modification. This converts Chopart's amputation into as perfect an operation as any performed on the foot; the resulting stump is excellent, the patient being able . . . to walk, not only on level ground, but up ladders, without difficulty."[1]

Malgaigne's Operation.

This amputation begins with the formation of two lateral flaps with a single incision. The point of the knife is introduced directly above the superior surface of the upper aspect of that part of the os calcis, which projects backward to form the heel, dividing at this point the tendo Achillis, passing downward and forward beneath the external malleolus (Fig. 99), thence

Fig. 99.

Fig. 100.



along the lower border of the os calcis, it ascends from here obliquely across the middle of the os cuboid to the dorsum of the foot, thence over the anterior border of the scaphoid bone

[1] Anatomy and Surgery of the Human Foot, p. 382.

(Fig. 100) downward over the inner side of the foot (Fig. 101), in a straight line to the centre of the external cuneiform bone (Fig. 102).

Fig. 101.

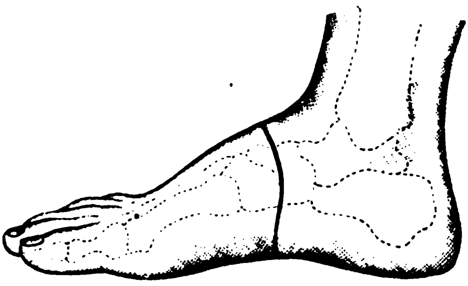


Fig. 102.

At this point the incision turns backward forming a right angle, passes over the centre of the heel and meets the other end of the incision at the original starting point. These flaps should now be dissected up from the bones sufficiently to uncover the medio-tarsal articulation and both sides of the os calcis. Care being taken to avoid opening or otherwise doing injury to the ankle-joint. The anterior portion of the foot is now removed by disarticulating the medio-tarsal joint in the same manner as directed in the performance of Chopart's amputation, after which the os calcis must be carefully separated from the astragalus, while the latter remains undisturbed in its relations to the ankle-joint. Notwithstanding the unfavorable appearance of the bones entering into the formation of this stump (Fig. 103), it is said that the patients on whom this operation have been performed are able to walk very satisfactorily.

The appearance of the stump after the closure of the flaps is represented in Fig. 104. Various modifications of this opera-

tion have been described and practised by J. Roux, L. Verneuil, and others; but since disarticulation of the tarsus under the

Fig. 103.

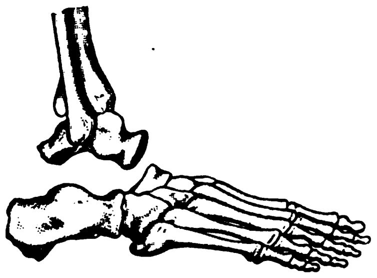


Fig. 104.

astragalus is now seldom performed, as the majority of surgeons prefer Syme's operation at the ankle-joint, it is thought unnecessary to enter more fully into details.

Disarticulation of the Foot at the Ankle-joint.

Prof. S. D. Gross says: "Although amputation at the ankle-joint has long been known to the profession, yet the credit of popularizing it is justly due to the teachings and influence of Prof. Syme, who performed it for the first time in 1842. Since then he has repeated it upwards of thirty times, and his example has now been so frequently followed by others, in America as well as in Europe, that it may be regarded as one of the established operations in surgery. Less dangerous than amputation of the leg in its continuity, it is particularly adapted to those cases in which there is caries of the posterior tarsal bones, especially the astragalus and calcaneum, without any involvement of the ends of the tibia and fibula. When such involvement exists, except in a slight degree, the limb should be taken off higher up, other-

wise it will be difficult, if not impossible, to prevent a recurrence of the disease."[1] Prior to describing Syme's amputation, it seems proper to give some attention to the chief factors on which the success of the operation depends. Dr. John A. Wyeth in his excellent prize essay, on the surgical anatomy of the tibio-tarsal articulation, with special regard to amputations at this joint, as deduced from eighty consecutive dissections, says: "In both the amputations at the *tibio tarsal* articulations (Syme's and Pirogoff's), surgeons agree that the perfect success of the operation depends upon the vitality, *i. e.*, the non-interference with the blood-supply of the inferior or calcanean flap. Descriptive and surgical anatomists and operative surgeons agree with remarkable unanimity, that the integrity of this flap is dependent upon its blood supply, partly from the *anterior and posterior peroneal* arteries on the outer side, but principally from the *calcanean* branches of the *posterior tibial* on the inner side of the ankle-joint. . . . . Apropos to the generally accepted idea of the origin of this principal blood supply, the following quotations are given: 'The *internal calcanean* consist of several large branches, which arise from the *posterior tibial* just before its division.'—Gray. Quain, while mentioning these vessels in his text only in a general way, gives them specially in his diagrams as branches from the *posterior tibial*, anastomosing with branches of the *posterior peroneal*. 'The *internal calcanean branches*, three or four in number, proceed from the *posterior tibial* artery immediately before its division.'—Wilson. 'The *calcanean arteries* are two or three branches from the lower part of the *posterior tibial*.'—Leidy. . . . I assert without equivocation that the arterial supply to the calcanean region, as given above, is not correct in the main, and that operative surgery at the ankle-joint, based upon the idea that the arterial supply to the calcanean flap is derived from the posterior tibial, is unsafe. . . . In seventy-two of eighty cases the *posterior tibial* bifurcated into its *plantar* branches on a line between the lower border of the internal malleolus and the middle or centre of the

[1] System of Surgery, vol. ii. p. 1034, Phila. 1866.

heel's convexity. In four of the remaining cases the separation occurred one-fourth of an inch, and in the other four cases one-half an inch *below* this line *M N* (see diagram). Any variations in the point of division tend, in all cases, toward the line of incision in amputations in this region. In thirty-

Fig. 105.

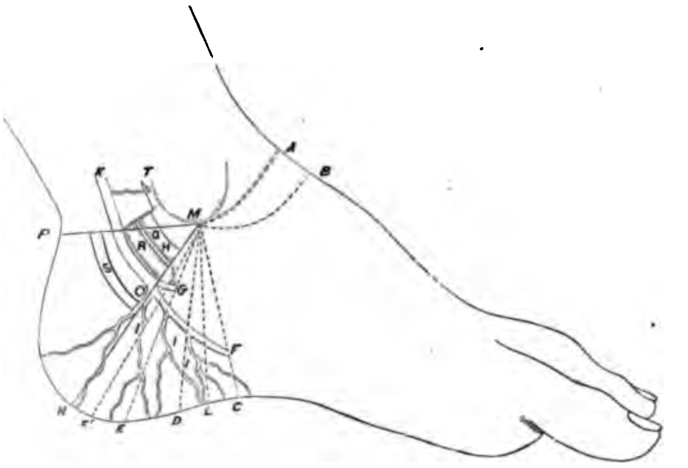


Diagram showing the arterial supply to the calcanean region, on the tibial side of the foot (drawn by the author, from the average of eighty dissections). *M.* Internal malleolus. *P M C N.* Tibio-tarsal quadrilateral, the surgical region of this articulation. *K.* Posterior tibial artery *O.* Its point of bifurcation into *G.* Internal plantar and *F.* External plantar artery. *I I I.* Calcanean branches of external plantar. *T* Articular branches from posterior tibial. *H.* Articular branch from internal plantar. *Q.* Tendon of tibialis posticus muscle. *R.* Tendon of flexor longus digitorum. *S.* Tendon of flexor longus pollicis. *M C.* The line of incision of Gross. *M L, M D, M E, M E'.* Lines of incision showing that the nearer the incision approaches the heel, the more danger is incurred of cutting off the principal blood supply to the calcanean flap, in amputation. *M N.* Line crossing the usual point of bifurcation of the posterior-tibial. *M A, M B.* Anterior incision.

eight out of eighty dissections (*almost one-half*) there was not a single *calcanean artery* derived from the *posterior tibial* (*K O*, see diagram). So it must follow that any line of incision that approximates the terminal bifurcation of this vessel will, in a great many cases, endanger the blood supply, and consequently the success of the operation. . . . From the standpoint of surgical anatomy, the incision recommended and practised by Prof. Gross, and represented in the above diagram by the line *M C*, is the most rational, since it is furthest removed from the

most constant blood supply to this inferior flap, viz., the *calcanean branches of the external plantar artery*."[1]

Fig. 106 represents the outlines of Prof. Gross's operation; and the directions for its performance I will give in his own language: "*Syme's Amputation* . . . is performed with two flaps, one of which is taken from the front and the other . . . from the sole of the foot, the two meeting at the outer and inner ankle. The best instrument is a large scalpel; the foot is placed at a right angle with the leg, and the circulation is controlled by means of the tourniquet applied to the popliteal artery. The operation is commenced by making an incision perpendicular or nearly perpendicular from the centre of one malleolus to that of the other, directly across the sole of the foot, and then carrying another, of a curvilinear shape with the convexity looking forward, over the fore part of the limb, so as join the two points of the former at an angle of 45°. The lines of these cuts are well seen in Fig. 106. The anterior flap is

Fig. 106.

now carefully raised, the astragalus disarticulated, and the posterior flap dissected off from the calcaneum, by passing the

[1] Am. Journ. of Med. Sci., vol. lxxi. p. 392.

knife closely over its surfaces, as in Fig. 107, in order to avoid wounding the tibial artery. The tendo Achillis being severed from its connections, the operation is finished by sawing away the two malleoli and a thin slice of the tibia, just enough to include its cartilaginous incrustation. The posterior flap thus formed, consisting of the thick and hardened cushion of the heel, offers an admirable covering for the exposed bones, to which it usually unites by the first intention, and which afterwards enables them to bear pressure with great facility. The

Fig. 107.

Fig. 108.

only objection to it is that, unless special care is taken in its adjustment, it may form a sac for the accumulation of matter, thus greatly retarding the cure. This, however, is generally easily prevented by the proper application of the bandage in dressing the stump at and for some time after the operation. Should this contingency, however, arise, relief must be afforded by a small puncture through the plantar surface of the flap. The appearance of the stump after the parts are healed is shown in Fig. 108. In performing this operation there are three points which deserve special attention. The first is not to have a redundancy of flap, which will seldom happen if they are both

shaped in the manner here described; the second is not to cut any holes into the posterior flap while severing its connections with the calcaneum; and the last is not to divide the posterior tibial artery prior to its separation into its plantar branches, otherwise sloughing of the soft parts might ensue from deficient nourishment. If these precautions be observed, it will be difficult to make a bad stump. When the cure is completed the limb will be from an inch to an inch and a half shorter than natural. When, in consequence of disease, the flaps cannot be formed according to the plan now laid down, they may be taken from the sides of the limb, including as much of the integument of the heel as possible. The operation is easy enough of execution, but the cicatrice after the healing of the stump will be much in the way of the patient's comfort, and may lead to the necessity of amputating the limb higher up."[1] Every step in the performance of this operation has been carefully detailed by Prof. Gross, and consequently it only remains for me to mention, in connection with the above, that, as a protective measure against the accumulation of fluid within the heel flap, in every instance a puncture should be made in its most dependent portion, and through it should be passed a drainage-tube. This precaution will frequently prevent sloughing and septic complications. The after-treatment requires no other special description.

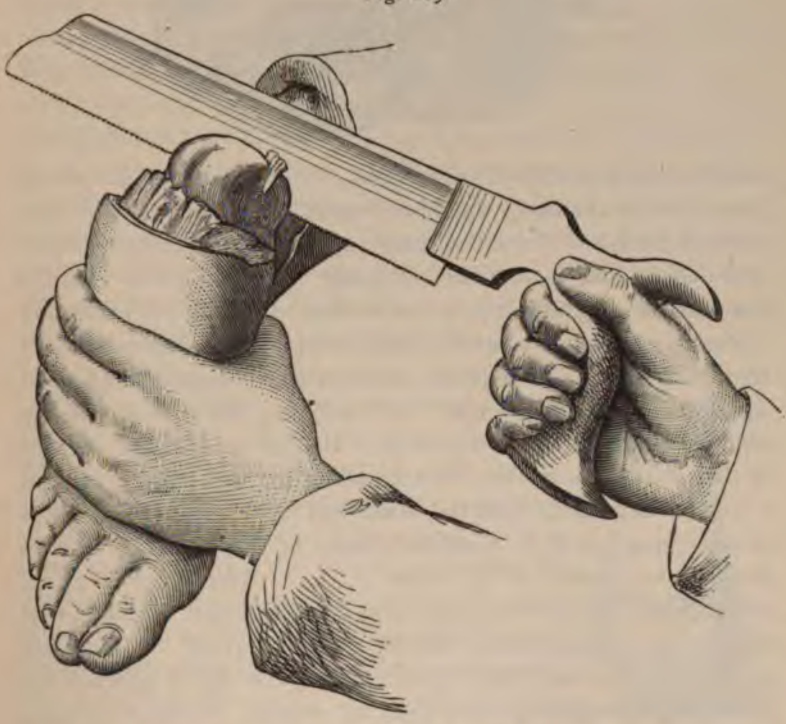
PIROGOFF'S AMPUTATION.

Syme's operation was modified in 1852 by Mr. Pirogoff, of Russia, who retains a portion of the calcaneum, thus giving greater length and rotundity to the stump. The soft parts are incised in exactly the same manner as has been recommended for the performance of Syme's operation. The foot being placed at a right angle with the leg, the first incision should be drawn from the centre of one malleolus to the centre of the other directly across the sole of the foot; the second incision should connect with the extremity of the first at an angle about 45°,

[1] System of Surgery, vol. ii. p. 1034, 1866.

and should pass over the dorsum of the foot so as to form a crescent-shaped flap. The anterior flap is now dissected up sufficiently to expose the ankle-joint which may be readily opened and the lateral ligaments divided by passing a strong knife between the astragalus and the malleoli, after which the foot can be dislocated, and the upper surface of the back of the os calcis exposed. The heel flap is dissected up sufficiently to clear the way for the saw. The limb is now steadied by an assistant while the surgeon extends the foot as much as possible,

Fig. 109.



and while it is still held in his left hand he applies a common saw to the os calcis immediately behind the astragalus, and the bone is cut obliquely downward and forward, so that the saw comes out directly behind the articulation of the os calcis with the cuboid. This part of the operation is well represented

in Fig. 109. The next step in the performance of this amputation consists in clearing and removing the malleoli together with a thin slice of the tibia. The appearance of the parts after the removal of the malleoli is well shown in Fig. 110. The

Fig. 110.

anterior and posterior tibial arteries, as well as any others which may bleed at the time, should be ligated, after which the cut surfaces of the bones should be neatly approximated, proper sutures introduced, and a suitable dressing applied. Prof. Heath's remarks on certain points in connection with this operation are certainly entitled to a careful consideration, but it is necessary to remember that he divides the os calcis less obliquely than most surgeons of the present age. In describing the removal of the malleoli he says: "The direction of the cut is to be the reverse of that in the calcaneum, the saw being applied parallel to, and a quarter of an inch from the lower end of the tibia in front, but sloping upwards so as to remove more of the posterior than of the anterior surface of the bone. . . . The piece of calcaneum should not be too large, and when the heel is prominent the incision should be less oblique than that given. If too little of the tibia is removed, the posterior angle is apt to prevent the heel being brought up so as to fit accurately. Pirogoff's amputation may be performed like Syme's, the heel flap being formed first by applying the saw from below before opening the ankle-joint, but this method is rather more difficult of execution, and there is a danger of applying the saw too far forward. Both Syme's and Pirogoff's operations may be performed without

opening the ankle-joint, by at once reflecting the front flap and sawing through the tibia and fibula above the malleoli."[1] The most essential difference in the operative procedures of different surgeons in the performance of Pirogoff's amputation consists in the greater or less obliquity given to the incision through the os calcis. Erichsen remarks on this subject that: "The advantages of the long oblique section of the os calcis over the shorter almost vertical cut originally made by Pirogoff are, as Busk has pointed out, that a larger surface of bone is brought into contact with the same ends of the bones of the leg, that the remaining piece of bone does not require to be tilted so much on its own axis, and that consequently the tendo Achillis is not put so much on the stretch, and that the thick skin of the heel, naturally in contact with the ground, still serves as the basis of support instead of the thin skin of the back of the heel, which is turned downward in the other method. The advantages of this operation over the ordinary mode of disarticulation consist in the stump being longer, to the extent of the thickness of the portion of the os calcis left in it, and being better adapted for pressure (Fig. 111); in the readiness of the union of the two applied osseous surfaces; and in the less likelihood of the supply of blood to posterior flap being interrupted, as its vascular communications are not much disturbed. These advantages are not, however, always real, and are in some degree counter-balanced by the liability to recurrence of disease in the portion of the os calcis left in those cases in which the operation is done for disease. When it is practised for injury, however, this objection does not hold good. Another objection which has been raised against this operation, consists in the supposition that the section of two osseous surfaces exposes the patient to increased risk of osteo-phlebitis and pyæmia. In the first case in which I performed this amputation the patient,

Fig. 111.

[1] Heath's Operative Surgery, p. 113, 1878.

a healthy lad, whose foot was removed for injury, died from this cause. But subsequent and extended experience has convinced me that there is no special liability to pyæmia after Pirogoff's amputation. After its performance patients can run; which they cannot do after amputation of the leg in any part."[1] The general law of surgery requires that no part of a limb be sacrificed unless its removal increases the patient's chances for life or bodily usefulness, and even after the surgeon has decided on an amputation he should always restrict his operation to the accomplishment of this primary object, and consequently never remove one inch of bone which is not made necessary by the circumstances of the case. The chief questions commonly considered after having determined on the removal of the foot, prior to the performance of the amputation, usually turns on the advantages and disadvantages of Syme's operation over Pirogoff's, and *vice versa*. In behalf of Syme's operation it may be fairly claimed that the healing of the wound is generally more prompt; and consequently the dangers from septic infection and other wound complications are relatively diminished; but unquestionably Pirogoff's amputation gives a more serviceable stump, the especial advantages of which are that the limb is not shortened, and the well-cushioned heel is preserved with its thick integumental covering instead of the thin skin which covers the posterior surface of the ankle. After the performance of Syme's operation the patient must be supplied with an artificial foot before walking becomes practicable; but after Pirogoff's amputation he can walk and even run without the aid of artificial appliances. Both Pirogoff's and Chopart's amputations are liable to be followed by an elevation of the heel due to a shortening of the muscles of the calf of the leg; and this may generally be obviated by proper treatment during the healing process. Should it, however, occur, it is easily remedied by a subcutaneous division of the tendo Achillis.

[1] Science and Art of Surgery, vol. i., 1878, p. 110.

MODIFICATION OF PIROGOFF'S AMPUTATION.

Numerous modifications have been practised in the performance of this operation, but they do not possess the merit of giving to it a wider adaptability, and only serve to show that various changes may be made in the operative procedures without seriously impairing the results. These modifications pertain to the direction given to the sawing of the bone, which has already been mentioned, and also to the placing of the sawn surfaces of the os calcis directly in contact with the articular surface of the tibia, without removing any part of the cartilaginous surface. Prof. Agnew mentions the following modification: "Several years ago, in performing this operation, instead of sawing off the malleoli and the articular surface of the tibia, I allowed them to remain, and placed the calcaneum in the mortise between the two; the union was complete, and was followed by a remarkably useful stump. In other instances I have done this, and with satisfactory results. . . . . It is not always, however, that such a disposition of the remains of the os calcis is possible. There is a remarkable absence of anatomical uniformity in the size of the os calcis as compared with the intermalleolar space. Frequently the former is too wide to enter the latter. When this is not the case, the above plan should be adopted in preference to the original one, as the calcaneum is less liable to be displaced. The union of the bones will be somewhat hastened by paring away the incrusting cartilage from the inner surfaces of the malleoli and from the articular face of the tibia."[1]

The incisions through the soft parts are essentially the same in the various operations, although Bontecou in forming the plantar flap cut from within outward.

Amputation of the Leg.

This operation may be performed through the upper, middle, or in the lower third of the limb. The operative procedures

[1] Principles and Practice of Surgery, vol. ii. p. 361.

may conform in most cases to the fancy of the surgeon, since it is now a recognized fact, that the success of the operation does not depend materially on the particular method employed in amputating the limb; but that equally favorable results may be reached by either the flap or circular methods. The chief object of the surgeon should be to meet the existing indications and to secure as far as possible, those conditions most favorable to a rapid healing of the amputation wound and a serviceable stump. The surgeons of the present age generally agree that complete drainage and complete and continuous approximation of the wounded surfaces are very essential factors in the healing of amputation wounds. These factors, having been secured and maintained, seldom fail to give satisfactory results, in fact we recognize them as two of the essential conditions in the antiseptic treatment of wounds. It is therefore the operator's duty to provide for these, and that method which enables him to accomplish this object most effectually, while the other conditions remain equally favorable will certainly yield the best results. It now follows that inasmuch as the patient after an amputation of any portion of a lower extremity generally remains constantly in the supine position, therefore the drainage tube should pass through the limb from the anterior surface to its posterior. I therefore prefer in all amputations on the lower extremities the lateral flap operation, or the circular method, and in the latter case there should be made an opening just in front of the bone in the anterior and posterior portion of this flap, through which the drainage tube is passed. There is some danger when the elastic India-rubber tube is employed that it will be compressed against the bone or some other firm substance, and in this manner become occluded, but the exercise of ordinary care will prevent this accident. Attention has already been called to the necessity of neatly approximating the flaps. The object of this is to prevent the formation of pockets which would soon be filled with wound secretion. In order that the operator may accurately approximate the flaps to each other, and also to the surfaces which they are intended to cover, it is necessary that they should be cut neither too large nor too small; and furthermore,

that they be *so well shaped* as to fit the wound as well as a neatly fitting kid glove fits the hand of the wearer. The perfect approximation of the musculo-cutaneous flaps is more readily accomplished than the skin, since a moderate pressure by virtue of their elasticity and bulk fills up important irregularities on the wound surfaces. However the musculo-cutaneous flap cannot be obtained in amputations performed in the lower third of the leg, and consequently whatever method is employed the flaps are composed of integument.

Amputation of Leg by Lateral Flaps.

This operation may be performed in any part of the lower third of the leg, but it should always be made as near as possible to the ankle-joint. Prior to the commencement of this amputation the surgeon should determine the point at which he will divide the bone, and having done this he may proceed by either of the following methods to the formation of the flaps, the length of which must be proportionate to the diameter of the limb at the point of the operation. In the first operative procedure, the point of the scalpel may be introduced in the centre of either the anterior or posterior surface of the limb, about two lines below the point at which it is intended to divide the bone, and carried from either of these points through a curvilinear line on the outer side of the leg in such a manner as to give the desired crescent-shaped flap. Another incision is now made on the inner side of the leg, which corresponds in every respect with the one already described on the outer side. The extremities of these incisions are connected together on the anterior and posterior surfaces of the leg. Both these incisions having been carried completely through the integument, the lateral flaps are then dissected up two lines above their apices, at which point the muscles are divided by a circular sweep of the amputating-knife down to the bones, which are then sawn transversely across. The flaps may now be examined with especial reference to their accurate approximation, and if found too large or improperly shaped, may be suitably

trimmed and fitted to the parts. The ligation of the arteries, introduction of a drainage-tube, the closure of the wound by the metallic sutures, and the application of a suitable dressing, completes the performance of the operation. This method of procedure is well adapted to an amputation through the lower third of the leg in close proximity to the ankle-joint, in which case the incisions may pass below the malleoli. There is another method which may be conveniently employed in the formation of the lateral skin flaps in amputations of the leg. This operative procedure commences with the performance in the usual manner of the circular operation. The surgeon having incised the integument with a single sweep of the knife, dissects it up as far as may be necessary to give sufficient length to the flaps, and then with another sweep of the knife, he cuts through all the soft parts down to the bones, which are promptly divided with the saw. He effects a lateral approximation of this flap, and with strong scissors or an ordinary scalpel, commences either at the anterior or posterior angle formed by bringing this integument together in the manner already described, and so cuts it that he forms two lateral flaps of proper size and shape.

TEALE'S AMPUTATION OF THE LEG.

The lower third of the leg is especially favorable for the performance of amputations by Teale's method. This operation consists in the formation of a long and short rectangular flap. The long flap is generally cut from that part of the leg which contains few large bloodvessels and nerves, and consequently when an amputation is performed by this method in the vicinty of the ankle-joint, the long flap is taken from the anterior surface of the limb, and the short one from the posterior. The first duty of the surgeon is to determine the point at which the bones are to be divided, and having accomplished this, he then determines by measurement the circumference of the limb at this point, since the rule given by Teale requires that the long flap should be perfectly square, and that its length and breadth be each equal to the half of the circumference of the limb

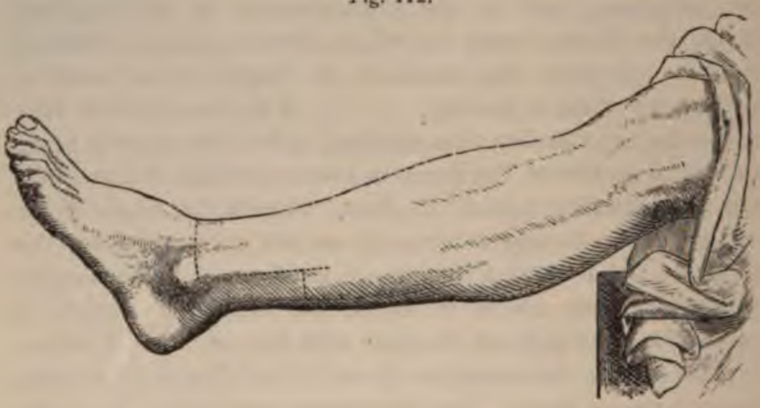
at the place where the bones are to be sawn; and therefore if the circumference be eight inches, the length and breadth of the flap should be each four inches, and the flaps should include all the soft parts of the limb. The posterior flap according to Teale should be one-fourth the length of the anterior flap, and include the remaining half of the circumference of the leg, but Christopher Heath thinks "it will be found in practice better to make the posterior flap one-third the length of the anterior. In the lower third of the leg. . . . it is convenient to take part of the anterior flap from the back of the foot, so as to bring the line of section of the bones as low as possible, but at whatever point the flap is made it should include the whole of the soft tissues."[1] Having determined on the point at which the bones are to be divided, the size of the flaps, and the locality from which they are to be taken, the next step consists in marking out carefully on the limb with ink, tincture of iodine, or some similar substance, the lines to be followed in making the required incisions. The above-mentioned author gives the following directions for further operative procedure:—

The lateral incisions running along the edge of the tibia and fibula, the deep fascia of the leg is to be similarly divided, and the whole of the muscles with the anterior vessels and nerve stripped up from the bones and interosseous membrane with the thumb nail or the handle of a scalpel. In this way a much more uniform and complete flap can be made than by using the knife. The posterior flap is best made by cutting from the skin to the bones, and the same precautions as regards the deep structures must be observed so that the deep vessels and nerves may be uninjured. The interosseous membrane is to be divided and the bones sawn together at the point previously determined, though the flaps may for convenience be reflected a trifle further. The ligation of the anterior tibial artery in the anterior flap, and the posterior tibial and the peroneal arteries in the posterior flap is now in order. The drainage-tube having been placed in position, the anterior flap having been doubled over the sawn ends

[1] Heath's Operative Surgery, p. 116, 1878.

of the bone, the extremity of the anterior flap having been brought in contact with the face of the posterior flap, it will then be observed, if these flaps have been made with care, that they fit together accurately, and the surgeon may proceed to intro-

Fig. 112.



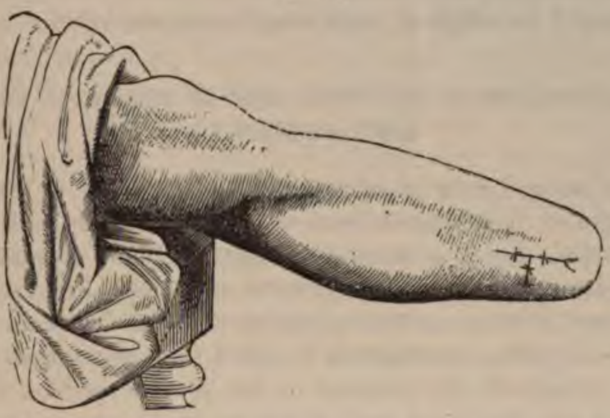
duce the required sutures and apply the proper dressing. Figs. 112, 113, 114, and 115 represent various steps in Teale's ampu-

Fig. 113.

tation. Fig. 112 shows the dotted lines to be followed in making the incision for Teale's amputation. Fig. 113 represents

the rectangular flap reflected. Fig. 114 presents the appearance of the stump with its adjusted flap, and Fig. 115 exhibits the

Fig. 114.



healed stump. The principal advantage claimed for Teale's amputation over the methods commonly employed consists in

Fig. 115.

its giving a loose and soft covering to the ends of the bones thus enabling more pressure to be made on the stump by the artificial limbs, which is unquestionably more important after

amputation of the thigh than elsewhere; but there are several disadvantages which are inseparable from it, and among others may be mentioned the difficulty in obtaining thorough drainage, and the necessity of cutting the bone shorter than would be necessary if two flaps of equal length were employed.

Amputation of the lower third of the Leg by the Circular Method.

This method may be advantageously employed in the performance of many amputations on both the upper and lower extremities; but it is especially adapted to those operations in which the surgeon desires to preserve only a skin flap, and does not expect to obtain perfect approximation of the same throughout all its parts; consequently I regard this operation as peculiarly adapted to the removal of the anterior portion of the forearm and the lower part of the leg in all cases where the surgeon does not wish to adopt the Lister method of treatment, with the intention of securing union by the first intention. Dr. John E. Link, of Indiana, has called the attention of surgeons to the peculiar adaptability of the circular operation to the treatment of amputation wounds by the open method. I have frequently observed in these cases that the circular flap, without any aid from the surgeon, gradually contracts down to the cut ends of the muscles, and while thus contracting, the aperture in it becomes steadily smaller until after the healing process has been completed, when an examination of the stump reveals an infinitesimal amount of cicatricial tissue. It may be safely asserted of the circular operation, that when the flap is made a proper length, and the wound treated by the open method, that the amount of cicatricial tissue in the stump cannot be lessened unless the wound has been caused to heal by the first intention. We therefore claim for this method of operative procedure a beautiful stump with a small amount of cicatricial tissue, and also a rapid and simple method of operating.

THE PERFORMANCE OF THE CIRCULAR OPERATION.

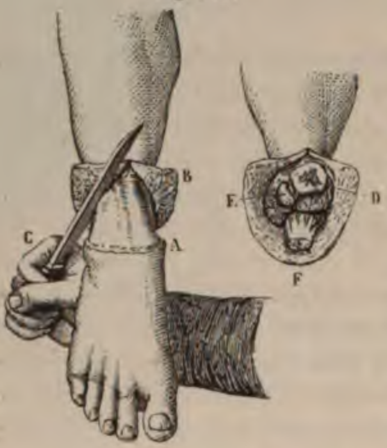
The leg being held in a convenient position, the surgeon assuming that position which enables him to perform the various parts of the operation with the greatest facility, passes the short amputating knife under and well over the limb, the point of this instrument being inclined downward at an angle of forty-five degrees or more, the cutting edge as near to the shank as possible is brought in contact with the integument which the operator now incises together with the subcutaneous fascia by a single sweep, an assistant immediately seizes the skin above the circular incision which in most cases he readily retracts sufficiently to give the required length of flap, but if he fails it must be dissected up and turned back like a cuff, after which the incision through the muscles should be made in strict accordance with the instructions given for incising the skin and subcutaneous fascia. The point at which the first incision is made depends on the disease or traumatism, but the second is determined by the required length to cover the bones. The soft parts having been divided down to the bones, the inter-osseous membrane is now incised by passing a scalpel between them, the saw is then properly applied and worked in such a manner as to sever both bones simultaneously, in order to avoid as far as possible the inconveniences which are otherwise liable to arise.

MODIFICATIONS OF THE CIRCULAR OPERATION.

The following wood-cut represents a modification of this amputation which was recommended by Malgaigne and Le Fort. During the performance of the operation, the surgeon assumes that position which enables him to accomplish his work with the greatest rapidity and ease, makes a circular incision of the skin above the malleoli in accordance with the rules which have already been given above, and connecting with it he makes a vertical incision, the length of which is proportionate to the diameter of the limb, but which commonly varies from four to

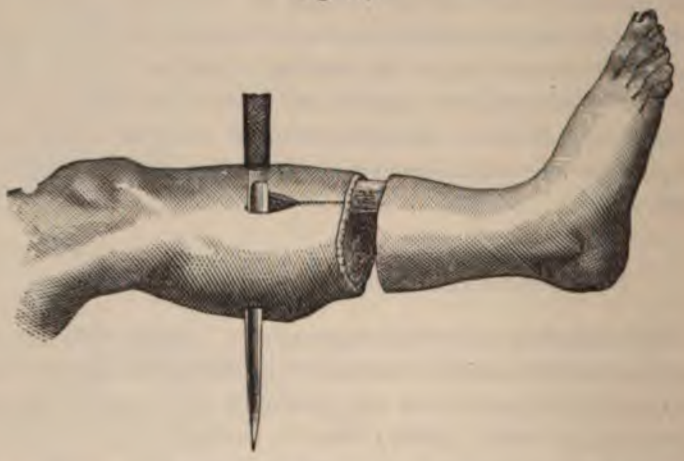
18

Fig. 116.



five centimetres. The skin having been dissected up, commencing on both sides of this incision, over the whole anterior surface of the leg, whilst that on the posterior surface remains adherent to the subjacent tissues, the surgeon cuts the muscles in the oblique direction indicated by the oval form of the cuff, which is raised only in front. After the division of the muscles, an assistant seizes the soft parts and draws them up sufficiently to be out of the way of the operator, who now proceeds to saw the bones and ligate the arteries. Ravaton's

Fig. 117.



method may also be regarded as a modification of the circular, although frequently described as a mixed operation. This operative procedure is represented by Fig. 117.

This operation commences with the formation of a circular

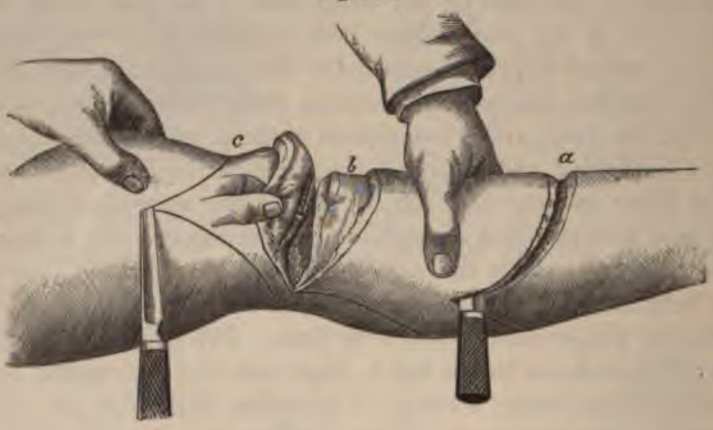
incision, which is carried through the integument far enough below the point at which the bone is intended to be sawn to give the required length to the flaps. This incision having been completed, the assistant now seizes the skin above the point where it has been divided, and draws it strongly upward, when the operator passes the knife again around the limb, severing the muscles down to the bone on a level with the lower border of the raised integument. The point of the scalpel is now passed through the soft parts on the outer side of the tibia down to this bone, at the point where it is intended to divide it, and thence carried directly downward to the circular incisions, after which another longitudinal incision is made on the posterior surface of the fibula, which commences at the point where this bone is to be divided, and is carried downward until it intersects with that which encircles the limb; or should the surgeon so elect, he *may by transfixion accomplish* the same object. In the latter method of procedure the surgeon ought to be especially careful to keep the knife as close as possible to the bones in order to give the proper dimensions to the flaps. The formation of this flap by transfixion leaves but a single one to be dissected up, whilst by the former method of procedure both flaps are thus loosened from the bones. These flaps are now drawn upwards by an assistant so as not to interfere with the surgeon, who immediately proceeds to carry a knife around the bones at the point where they are to be sawn, thus dividing the periosteum and the other remaining soft tissues, and then completes the operation by sawing through the bones.

Musculo-Cutaneous Flap Amputations.

These operations may be employed on the upper third of the leg, through the knee-joint or any portion of the thigh. The operative procedure may be that which is commonly designated as the antero-posterior, or the lateral flap operation; and the flaps may be formed by transfixion or by cutting from without inward. In some instances the operator may even prefer to form one flap by cutting from without inward, and the other

by transfixion. The dimensions of the flaps in the antero-posterior operation frequently vary, and because of this variation they are often designated as the long anterior and the short posterior, but the majority of operators in the performance of the *lateral flap operation* endeavor to give to each of the flaps the same length. The advantages claimed for the former method of operative procedure due to an inequality in the length

Fig. 118.



of the flaps, are, in the first instance, more perfect drainage, and secondly a better stump due to the cicatrix being posterior to the bones. The antero-posterior operation is well shown in the preceding illustration (Fig. 118).

Flap Amputation of the Leg, Antero-Posterior Method.

In the performance of amputations of the leg, the older surgeons commonly removed the limb a few inches below the knee at a site designated by them as the point of election; but modern surgeons are less inclined to operate in this locality, and some even regard it as a suitable point for rejection. Amputation of the leg at the point of election may be conveniently performed by the antero-posterior method as follows: the operator having assumed the proper position, may commence the operation by

the formation of an anterior flap—the dimensions of which must correspond to the diameter of the limb, and the proportion of the stump which it is intended to cover—by the introduction of the point of the scalpel either on the inner or outer side of the limb—and well back on the same; and when it is the intention of the surgeon to place the cicatrix behind the bones, the knife is first carried downward and forward, then upward and backward, thus forming a semilunar or ovoidal shaped incision. This incision having been carried down to the bones and the flap dissected up, it is placed in charge of an assistant, and the surgeon introduces the point of the amputating-knife or catlin at the highest point of the angle formed by the anterior flap and on that side of limb nearest to the operator; the instrument is then thrust through the soft parts of the leg, care being taken to keep it close to the bones, its cutting edge parallel with the same, while its point should make its exit at the highest point of the angle of the incision on the opposite side of the limb, and afterwards it is carried by a sawing motion downward and backward through the tissues so as to give the proper shape and size to the posterior flap. The formation of the flaps having been completed, the next step in the operation consists in clearing the bones of all soft tissues at the point at which they are to be divided, and this is most conveniently done with the scalpel, which is caused to sweep around them, and then thrust between them, in this manner preparing the bones for the saw. The sawing of the bones, ligation of the arteries, and the various details required in the management of the stump need not be described here.

Amputation at the Knee-joint.

Prof. Christopher Heath remarks that "*Amputations at the knee-joint* . . . may be variously modified by leaving or removing the condyles and patella. A large anterior skin flap is to be marked out by carrying an oval incision from one condyle to the other and as low as the tubercle of the tibia. This being dissected up for a short distance the *ligamentum patellæ*

and capsule of the knee-joint are to be divided, and the joint thoroughly opened. The knee being now flexed by one assistant and the thigh supported by another, the operator cuts the lateral and crucial ligaments in that order, and passes the knife backward horizontally between the bones. Turning the blade behind the tibia as soon as possible, he then cuts a flap of corresponding length from the back of the limb, and the operation is completed. The popliteal artery . . . and probably the vein will require ligature and will be readily found in the posterior flap; the external saphenous vein also sometimes bleeds. The patella can be drawn down into the inter-condyloid notch with the anterior flap to meet the posterior flap, from which the muscular fibres of the calf should be removed if they are redundant, but the bone will generally be drawn up again in front of the condyles in the process of healing. A better stump will in most cases be formed by removing the patella, and this may be done either by cutting above it when opening the joint so as to leave it attached to the tibia, or, better, by carefully dissecting it out of the flap when the amputation has been completed."[1] Gritti's modification of this operation consists in the removal of the condyles and the articular surface of the patella with the saw, and the cut surfaces will come in contact when the anterior flap is brought down. Prof. Heath gives the following directions: "In removing the articular surface of the patella, it will be found convenient to grasp the flap firmly with the left hand, and to press the bone firmly down upon the femur whilst the saw is applied vertically; an assistant should hold the patella with the lion-forceps applied transversely until a groove for the saw has been made. If this operation is selected, the posterior flap need not be so large as in the former amputation, but the patella does not commonly unite, being drawn up in front of the femur, where it gives a very useful attachment to the extensors of the thigh."

"FALLACIES.—In all these operations a long broad skin flap in front is essential, and it is most important that the vitality of

[1] Loc. cit. p. 121.

the skin should not be interfered with by the knife. In opening the joint, it will be found impossible to divide the crucial ligaments satisfactorily until the lateral ligaments have been cut so as to allow the femur and tibia to drop asunder, and there is the liability to break the point of the knife against the spine of the tibia, or to perforate the popliteal vessels."[1]

AMPUTATION AT THE KNEE-JOINT BY THE CIRCULAR INCISION.

This operation commences with a circular sweep of the amputating knife around the leg at the proper distance below the knee-joint while the limb is kept in the extended position. The operator may expedite the completion of this operation by the formation of a short lateral, vertical incision on either side of the limb, which intersects the circular. The integument should now be dissected up and turned back like a cuff in order that the surgeon may divide the ligamentum patella, capsular and lateral ligaments while an assistant strongly flexes the limb, after which the disarticulation will be easily completed. The removal of the patella from the flap by the aid of the scalpel, and so much of

Fig. 119.

the condyles as may be advantageous with the saw, may constitute the next step in the operation. The formation of the flap,

[1] Loc. cit. p. 121.

Fig. 120

disarticulation of the joint, and the appearance of the stump immediately after its closure are represented in Figs. 119 and 120.

CARDEN'S MIXED AMPUTATION AT THE KNEE-JOINT.

This operation is represented in the subjoined wood-cut, Fig. 121, and is performed by two incisions, the one a circular, just beneath the lower border of the patella, and the other a flap

Fig. 121.

including the whole calf of the leg. This muscular mass may be made to fit accurately over the end of the femur, but the

objection has been raised that the nerves which it contains, may prevent the patient from bearing pressure on the stump. Another, and a better method, which is also designated as Carden's was originally described in the April number of the *British Medical Journal* of 1864, in which the same principles are involved, although the order of procedure is reversed; the circular incision being made on the posterior aspect of the limb, and the flap intended to cover the stump being cut from the anterior surface. This amputation consists in the formation of a rounded integumental flap from the front of the knee sufficiently long to cover the entire stump, which makes it necessary that the incision should extend below the tubercle of the tibia. This flap is then dissected up, the knee flexed, and the remaining soft parts divided by a single circular sweep of the knife down to the bone, and then retracted, after which disarticulation may be effected or the femur may be sawn through at the base of the condyles. The operation is then completed by the ligation of the arteries, the introduction of the drainage-tube, and bringing

Fig. 122.

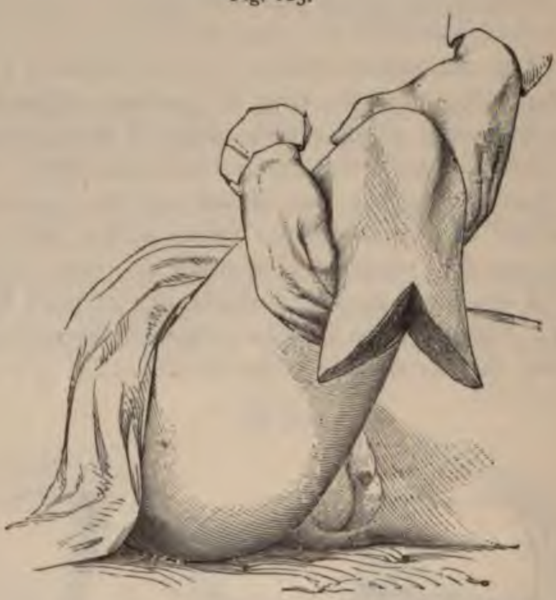
the anterior flap down over the end of the bone, and attaching it with metallic sutures to the edge of the posterior wound. The appearance of the stump immediately after the completion of the operation is shown in the illustration (Fig. 122).

Lateral Flap Amputation.

The lateral flap amputation, or that more properly called the bilateral flap method, affords better facilities for drainage in any

portion of the lower extremities, than that which commonly prevails when the other methods are employed. The flaps may be composed entirely of skin, or they may contain integument and muscle. Fig. 123 represents the appearance of the stump after performance of an amputation by the lateral method.

Fig. 123.



Dr. Stephen Smith, of New York, gives the following directions for the performance of amputation at the knee-joint by the lateral flap method: "Select a large scalpel, and commence an incision about one inch below the tubercle of the tibia, and cut to the bone; carry it downward and forward beyond the curve of the side of the leg, thence inward and backward to the middle of the leg, thence upward to the middle of the popliteal space; repeat this incision upon the opposite side; raise the flap, consisting of all the tissues down to the bone, until the articulation is reached, divide the lateral ligaments, enter the joint, and sever its connections internally and externally. . . The flaps completely cover the condyles . . . and are

readily approximated, leaving ample space for direct drainage at the upper angle of the wound; a drainage-tube may be inserted if necessary; the flaps are well nourished, and union takes place rapidly, giving a well-rounded stump with the cicatrix sunk in the inter-condyloïd fossa."[1]

Flap Amputation of the Thigh by Double Transfixion.

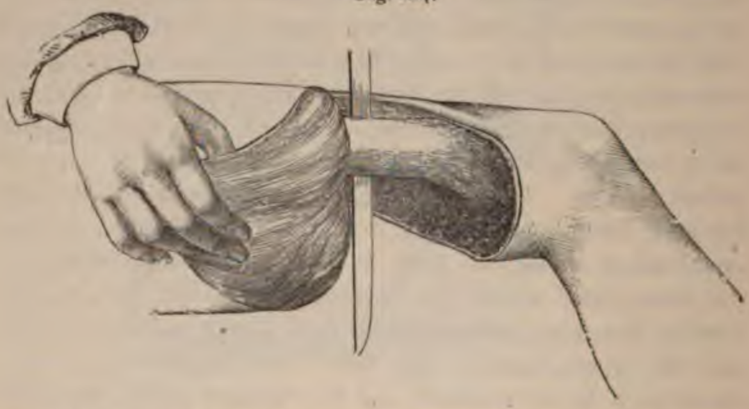
Amputation in any portion of the shaft of the femur may be readily performed by double transfixion; but the antero-posterior flaps (Fig. 118, *c*), can be more rapidly cut in this way than any other. The operator having assumed that position which enables him to perform the various parts of the operation with the greatest ease, grasps the soft tissues in front of the thigh with his left hand, and raises them so as to have as large a flap in front as possible; at the same time being careful to exert the greatest power on that portion of the soft parts directly above the point where the knife is entered, and but little where it makes its exit. The amputating knife is now thrust through the limb, being kept as near to the bone as possible, its edge raised barely enough to keep it from coming in contact with the same, after which the instrument is carried by a sawing motion downward and outward, thus giving sufficient length and the proper shape to this flap. The anterior flap is now drawn back by an assistant, and the operator passes the knife behind the bone, and cuts downward and outward, thus forming a posterior flap which is commonly somewhat longer than the anterior. Both flaps being retracted, the knife is carried around the bone as close to the flap as possible, for the purpose of dividing the remaining soft tissues, and the saw is then applied. The completion of this operation need not be further described, since the rules governing our action in this case are the same as in other amputations.

[1] Operative Surgery, p. 627, Boston, 1879.

VERMALE'S AMPUTATION OF THE THIGH.

This operation is tersely described by Erichsen as follows; "The outer flap should always be made first. The point of the knife, being entered in the middle of the thigh, about three inches above the upper border of the patella, is carried close round the bone, and brought out through the centre of the ham; the flap is then cut downward and outward; the knife, being entered again in the upper angle of the incision, is carried close round the bone to its inner side, and the inner flap made by a sweeping cut (Fig. 124). Unless the blade be kept in contact

Fig. 124.



with the bone in this situation, the femoral artery is very apt to be split. The flap being then retracted, the bone is cleared by two sweeps of the knife, and sawn about four inches above its articular surface."[1]

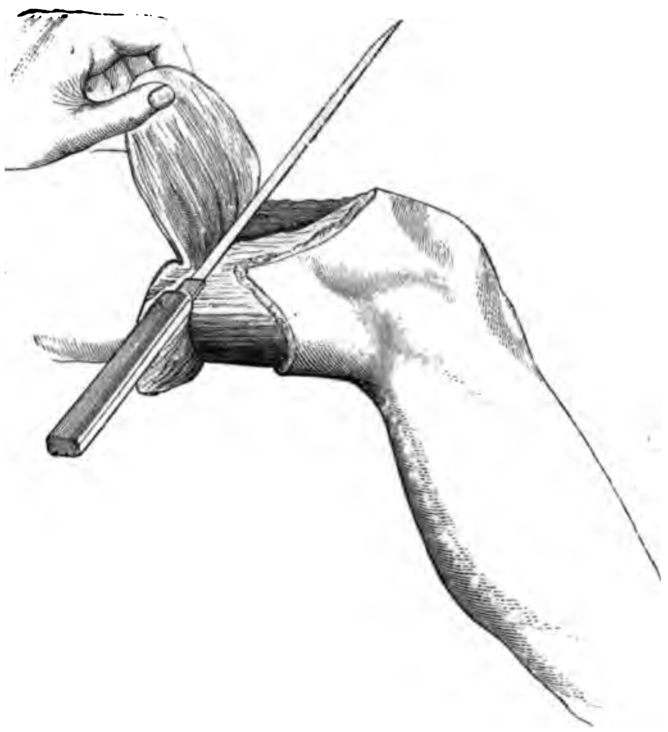
MODIFIED FLAP AMPUTATION OF THE THIGH.

The modified flap amputation may be employed on patients who are very muscular, or, under all circumstances, when the operator desires for any reason to diminish the bulk of the flaps.

[1] Science and Art of Surgery, vol. i. p. 120, Amer. ed., Philada. 1878.

This operation should be performed by cutting from without inward, care being taken to give the proper shape to the flaps whether the method of procedure be the antero-posterior, or lateral flap operation, and the incisions should be carried only through the skin and connective tissues. The surgeon dissects up these flaps and only includes in them so much muscular tissue as he may think advantageous (Fig. 125). The remain-

Fig. 125.



ing mucular tissue is now divided by a circular sweep of the knife, and the soft parts drawn well upward, and the bone sawn at that point.

Amputation through the Trochanters.

This operation has been occcasionally performed for necrosis involving the shaft of this bone, but it is rarely employed in cases of injury, and should always be discarded in favor of amputation at the hip-joint in cases of malignant disease, on account of the diminished probability of the return of the malady after the performance of the latter operation, which more than counter-balances the increased danger to the life of the patient. No description of this operative procedure is required, since the same methods are applicable here as in other portions of the thigh. It should also be remembered that it is very easy to convert this amputation into a disarticulation, by dissecting out the head and neck of the femur, if these parts be found diseased.

Amputation at the Hip-Joint.

This formidable operation was first successfully performed by Perrault, of St. Maure, in 1773. In the following year it was done in England by Kerr, of Northampton, and the patient lived seventeen days; but it was not till 1793, when Larrey performed it for the first time for gunshot injury, that the operation was placed on a firm basis in surgical practice, either civil or military. The successful performance of this bold operation seems to have marked a new era in the progress of surgery, and demonstrated the wonderful recuperative power possessed by man, as well as the daring spirit which has characterized the surgical profession from that time to this. Severe gunshot injuries causing extensive comminution of the bone, great and irreparable loss of the soft parts, especially when the principal bloodvessels and nerves are implicated, as well as malignant growths and other morbid conditions, require this amputation. Various operative methods are employed for the removal of the limb at this joint, giving the surgeon sufficient scope for selection; but the success of the operation will depend much more upon the avoidance of such complications as hemorrhage and

septic absorption, than the operative procedure. The method of procedure should be selected with especial reference to the avoidance of these serious mishaps. Various excellent instruments have already been mentioned in another part of this work, and when these are skilfully employed during the performance of this operation, the quantity of blood lost will not seriously endanger the life of any patient, and a strict adherence to Prof. Lister's antiseptic method of treatment obviates the danger arising from septic complications; and furthermore since it limits suppuration to the minimum, and always aims at securing union by first intention it will certainly greatly diminish the frequency of secondary hemorrhage.

Flap Amputation at the Coxo-Femoral Articulation.

This operation may be performed by either antero-posterior or lateral flaps; and those commonly employed are properly designated as the musculo-cutaneous; although some surgeons prefer that they should be composed chiefly of integument and cellular tissue. The formidable character of this operation renders it incumbent on the surgeon, prior to commencing this operative procedure that he provide carefully for all the details of the same, and also be prepared to meet any emergency which may arise. The operator ought therefore as a preliminary step to select at least three well-trained surgical assistants, and also a competent physician to administer the anæsthetic.

It is highly important that the physician having charge of the administration of the anæsthetic should possess the confidence of the operator to such a degree, that the latter may entirely withdraw his attention from this part of the operation, and concentrate his thoughts on that which is more immediately connected with the removal of the limb. The patient having been fully anæsthetized may then be placed in that position on the operating table, which enables the operator to accomplish the operation most readily. It is generally conceded that this is best accomplished when the patient is so placed that the pelvis on the diseased or injured side projects over the lower

border of the table, the leg at the same time being flexed on the thigh, and the thigh slightly flexed on the body, the whole limb moderately abducted, and the scrotum drawn toward the healthy side. The position and duties of the surgical assistants should be as follows: No. 1 should take charge of the abdominal tourniquet, and may stand on either side of the patient, while the instrument should be applied to the abdominal aorta a little below and to the left of the umbilicus. No. 2 should stand on the opposite side to the operator and be prepared to grasp the anterior flap and compress the femoral vessels. No. 3 should grasp the limb firmly, and be prepared to move it as required during the operation. All things now being in readiness, the operator assumes that position which enables him to perform this particular operation with the greatest facility, a position which must depend on the limb which he is about to remove, as well as other circumstances, and he now feels for the tuber-ischii and the anterior superior spine of the ilium, which are the anatomical guides in this operation. The blade of the amputating knife should be at least twelve inches in length, and its point should be lateral, and the anterior flap cut in different ways according to the side of the body on which the operation is made. If it be on the left side, the knife should be entered as shown in Fig. 126, *i. e.*, about two inches below the anterior superior spine of the ilium, or midway between it and the trochanter major; the knife is now carried directly across the joint on a line parallel with Poupart's ligament, and at the proper depth to insure the opening of the joint capsule, and finally it is brought out on

Fig. 126.

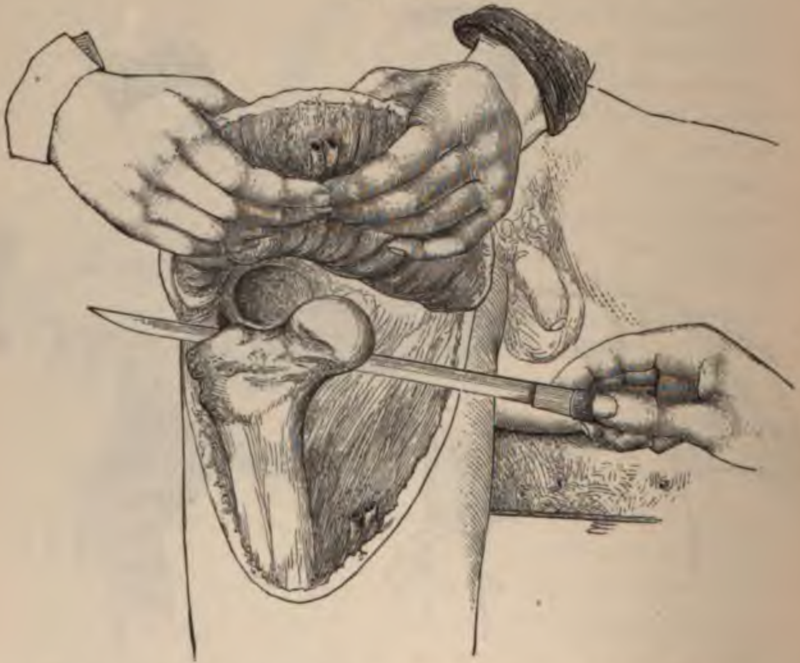
the inner side of the limb at the juncture of the thigh with the scrotum. In the performance of this part of the operation the surgeon should carefully avoid wounding the scrotum or the opposite thigh; the back of the knife must run parallel to, but not against the pelvis, and the point must not be held too high, lest it enter the obturator foramen. The knife is now carried quickly downward and outward by a sawing motion, thus forming an anterior flap of the proper length and shape, which is instantly seized and drawn backward by the assistant, who at the same moment so compresses the vessels between his fingers as to completely arrest all hemorrhage. The appearance of the parts at this stage of the operation is well shown in Fig. 127.

Fig. 127.

The surgeon now carries the amputating-knife under the limb and places its heel at the upper and inner angle of the

wound formed by the anterior flap, after which this knife is drawn through a semicircular line which intersects the same wound at its upper and outer angle; this incision is then carried down to the bone, thus forming a posterior flap of the proper size and shape. The dimensions of this flap must be proportioned to the diameter of the limb and the length of its anterior fellow. The flaps having been completed, the next step in the operation consists in disarticulating the hip-joint, which may be quickly accomplished by first passing the knife around the joint, then dividing the capsular and other ligaments, while the flaps are well drawn up by an assistant. Fig. 128 represents the formation of the posterior flap by cutting from within outward and downward.

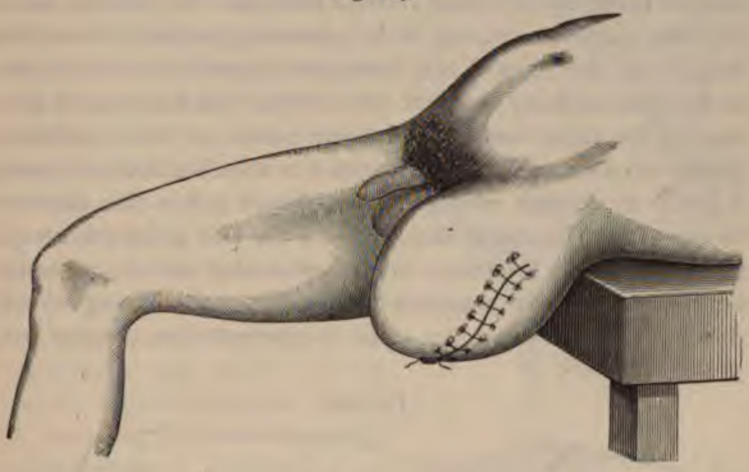
Fig. 128.



The assistant having charge of the limb, in order to facilitate the disarticulation of the joint, should now forcibly abduct and

carry it backward while the surgeon is opening the capsule and cutting the posterior flap. This operation having been properly performed, the surgeon being careful to preserve a long anterior and a short posterior flap, there will be no reason to find fault

Fig. 129.



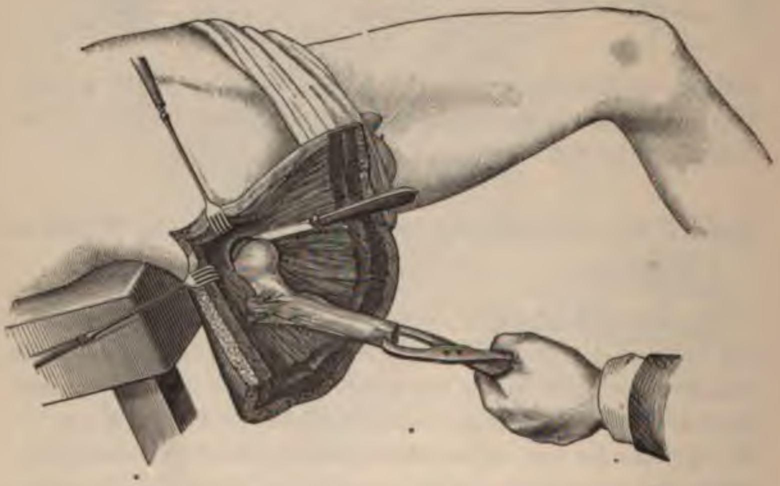
with the facilities given for the proper drainage of the wound. The appearance of the stump after the closure of the flaps is well shown in Fig. 129.

Amputation at the Hip-Joint by a Circular and Vertical Incision.

The soft parts are quickly divided down to the bone about five inches below the superior border of the trochanter major by a single powerful sweep of the knife, and all the bleeding vessels, veins as well as arteries, are immediately ligated with catgut. If the operator for any reason anticipates trouble from hemorrhage during the performance of the operation, it would then be advisable, prior to making the circular incision, to cut down on the femoral vessels in Scarpa's space and ligate both the artery and vein, or otherwise control the flow of blood through them by the aid of suitable forceps above and below the point at which

they are to be divided by the circular incision. These vessels are uncovered and brought within reach by a perpendicular incision. However, in all cases where other adequate means for the control of the hemorrhage is at hand, the operator will first carry the circular incision down to the bone, and then proceed to make the so-called vertical incision. He should select for this purpose a strong knife possessing a blade of suitable length, and the point of this instrument should be carried down to the bone midway between the anterior inferior spinous process of the ilium and the superior border of the trochanter major; then drawing it on a curved line over the ilium, keeping it firmly in contact with the bone, thence across the superior border of the trochanter major; and from this point downward midway between the centre of this eminence and its posterior border; and finally complete the incision by carrying it still downward in a straight line until it intersects the circular cut.

Fig. 130.



This vertical incision should now be carried down to the bone at every point, and while the limb is supported by the assistant, the surgeon may proceed to dissect up the soft parts covering

the head of the femur and that portion of the bone situated above the circular incision. Having proceeded with this dissection to its completion, or as far as it may be conveniently carried without a division of the bone, he may then divide the bone at the point where it is crossed by the circular incision. The lower portion of the upper segment of this bone is now seized and held firmly with strong forceps, while the flaps formed by the vertical incision are drawn well back in order that the surgeon may readily disarticulate the hip-joint. This part of the operation is well shown in Fig. 130, by which illustration it will be observed that it is frequently performed by a circular and simple vertical incision; but the vertical incision with the curve at its upper extremity will be found to afford more room for the surgeon's manipulation, and is therefore preferable. The appearance of the completed operation is shown in Fig. 131.

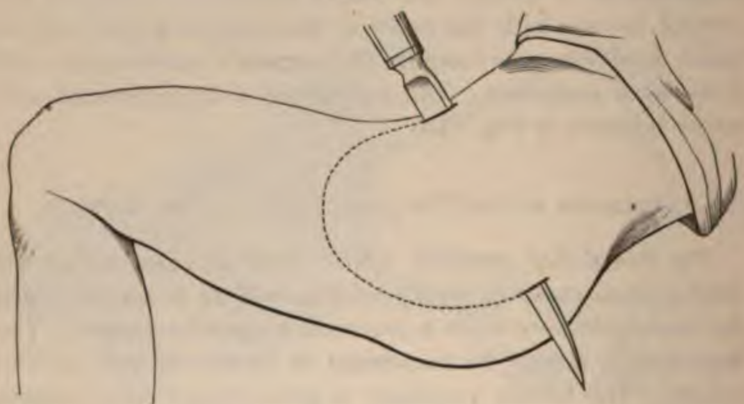
Fig. 131.

Amputation at the Hip-Joint, Lateral Flap Method.

The lateral flap operation affords better drainage during the healing of the stump at the hip-joint, as well as in the thigh and leg, and ought therefore to be preferred to any other method. The flaps may be formed by transfixion or by cutting from without inward. The former procedure is generally preferred because of the greater rapidity and ease with which the object is accomplished. Prof. S. D. Gross gives the following terse directions for the performance of this operation: "In the lateral amputation, the external incisions should always be made first, though this is not so important when there are skilful assistants,

of whom there should be at least four; one for administering chloroform, two for retracting the flaps and compressing the arteries, and one for holding the limb. If these matters be properly attended to, the operation is a comparatively easy one, and may often be executed in an almost incredibly short time, and with the loss of hardly a few ounces of blood. The buttock being well brought over the edge of the table, the thigh pretty widely separated and everted, and the femoral artery compressed over the brim of the pelvis, the knife, which should be upwards of a foot in length is entered, supposing the operation is performed on the left limb, immediately below the tuberosity of the ischium, and made to issue at a point midway between the anterior superior spinous process of the ilium and the great trochanter. The external flap is now formed by cutting downward and outward in close contact with the bones, for at least four inches, especially if the subject be at all muscular. An assistant is ready to seize and retract the flap the moment it is fashioned, as well as to compress the orifices of the bleeding

Fig. 132.



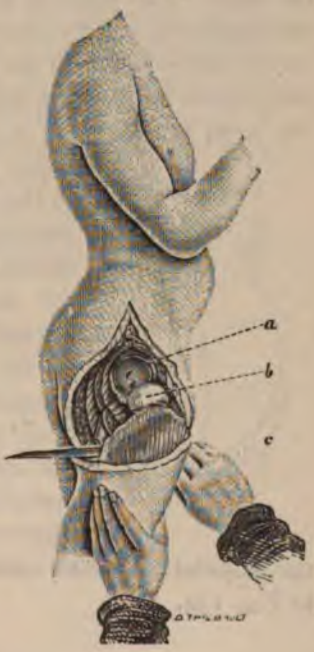
vessels. Reinserting the knife into the upper angle of the wound, it is rapidly pushed down along the inner surface of the bone, so as to form a large flap in that direction, to compensate for the small one on the outside. The assistant having charge

of the femoral artery in the groin now grasps the divided vessel, at the same time lifting up the flap. The next step of the operation is the disarticulation, which is readily effected by opening the upper and inner part of the joint, and then swiftly carrying the knife round the head of the bone, previously rendered prominent by depressing the knee. The arteries are now secured, first the femoral, and successively any other that may require the ligature, the assistants maintaining the compression until each vessel is ready to be tied."[1] Fig. 132 represents the formation of the external flap.

Amputation at the Hip-Joint, Oval Method.

This operation has been occasionally employed for the removal of an extremity at this articulation, and it is claimed, that on a *slender limb* it yields an admirable stump. The incisions occupy a space between the anterior superior spinous process of the ilium and the trochanter major, and intersect a little below, and to the inner side of the tuberosity of the ischium; thus forming the inferior angle of the wound. The appearance of the parts is represented in Fig. 133. The operation commences by the formation of a triangular or V-shaped incision, the apex of which should be situated sufficiently high to enable the operator to readily enter the articulation. There are two recognized methods of procedure. In the first the point of the knife is entered below the anterior superior spinous process of the ilium,

Fig. 133.



[1] System of Surgery, vol. ii. p. 1043, Philada. 1866.

while in the other the starting point is over the centre of the superior border of the trochanter major. It will be observed in both cases, that the incisions are commenced on the outer side of the limb, and that the operation begins by making two superficial oblique incisions; and furthermore, that these incisions in each instance take about the same direction, one being forward, inward, and downward, while the other is backward, outward, and downward, and these meet in a transverse line on the inner side of the thigh. These initial incisions and likewise the other steps of the operation are most conveniently made while the patient is lying on the healthy side. The formation of these oblique superficial incisions should be immediately followed by an oblique division of the muscles around the capsular ligament which are freely incised around the border of the cotyloid cavity. Dislocation of the head of the femur is now produced by strongly abducting the limb. The point of the knife is then introduced into the articulation to cut the round ligament; and the surgeon afterwards carries it behind the head of the bone, and completes the amputation by dividing the remaining soft parts, which contain the large vessels, with a single stroke. The assistant, in the mean time, should follow with his hands in the wound closely behind the knife, and compress the vessels the moment they are divided. It is always desirable to divide the integument over the entire circumference of the thigh at the commencement of the operation; but the operator will generally find it advantageous to cautiously avoid the division of the large vessels and the soft parts surrounding them, until disarticulation has been accomplished. The appearance of the parts after the closure of the amputation wound made by the oval method is represented in Fig. 134.

Fig. 134.

Modified Flap Amputation at the Hip-Joint.

This operation consists of the formation of tegumental antero-posterior flaps, which are cut from without inward, and the muscles are afterwards divided on a level with the joint by a circular incision. This method has been successfully employed by several American surgeons, and among others may be mentioned the late J. Mason Warren, of Boston, Mass. The chief advantages which can be claimed for it are those which belong to skin flaps.

Single Flap Amputation at the Hip-Joint.

The following excellent description of this amputation is given by Dr. Jno. Ashhurst, Jr.: "In this operation, a single large anterior flap is cut, either by transfixion (Manec), or from without inward (Plantade, Ashmead). The soft parts on the back of the limb are divided by a circular incision, either before or after disarticulation. In other forms of this operation the flap has been taken from the inside, or even from the back of the limb. The single flap method might be desirable in a case in which laceration of the soft parts was such as to forbid any other, but, when the surgeon has a choice of operations, it is better to employ either the oval or modified circular, or the double flap method of Guthrie."[1]

[1] Principles and Practice of Surgery, p. 129, Phila. 1871.

CHAPTER VI.

PRELIMINARY CONSIDERATION OF THE AFTER-TREATMENT OF WOUNDS. DISEASE GERMS: THEIR ORIGIN, NATURE, AND RELATION TO WOUNDS. COMMENTS ON THE DIFFERENT FORMS OF AFTER TREATMENT. CONCLUSIONS, ETC.

SPONTANEOUS generation is so intimately connected with the germ theory of disease, that I shall preface my remarks with a brief *résumé* of the former subject.

The ancients supposed that the low forms of life were generated in the matters in which they made their appearance.

"Lucretius, who had drunk deeper of the scientific spirit than any poet of ancient or modern times except Goethe, intends to speak as a philosopher, rather then as a poet, when he writes that 'with good reason the earth has gotten the name of mother, since all things are produced out of the earth, and many living creatures even now spring out of the earth, taking form by the rains and the heat of the sun.' The axiom of ancient science, 'that the corruption of one thing is the birth of another,' had its popular embodiment in the notion that a seed dies before the young plant springs from it; a belief so widespread and so fixed, that St. Paul appeals to it in one of the most splendid outbursts of his fervid eloquence: 'Thou fool, that which thou sowest is not quickened except it die!' The proposition that life may, and does, proceed from that which has no life, then, was held alike by the philosophers, the poets, and the people of the most enlightened nations, eighteen hundred years ago; and it remained the accepted doctrine of learned and unlearned Europe, through the middle ages, down even to the seventeenth century."[1] The first spark of light that penetrated this primi-

[1] Huxley's Lay-Sermons, Addresses, and Reviews, p. 346.

tive darkness came from an Italian physician, Francisco Redi, in 1668. Redi's experiments prove that maggots are generated not in dead flesh, but from eggs deposited by blow-flies. He was the first to give utterance to this remarkable hypothesis: "No life without antecedent life."[1] This work begun by Redi was continued by Vallisnieri, Swammerdam, and Reaumur, "who succeeded in banishing the notion of spontaneous generation from the scientific minds of their day. Indeed, as regards such complex organisms as those which formed the subject of their researches, the notion was banished forever."[2]

The improved microscope brought to light a world of life in the form of minute organisms, too small ever to have been seen by the unaided eye, and their diminutiveness seems to have suggested some mysterious transition of matter into living bodies. Here, again, arose the controversy with regard to spontaneous generation. The affirmative of the question was advocated by Buffon and Needham; the former postulating his "organic molecules," and the latter assuming the existence of a special "vegetative force, which drew the molecules together so as to form living things." The doctrines announced by Needham, in 1748, were forcibly opposed by Abbi Spallanzani, in 1777, who has shown that if either vegetable or animal infusions are boiled a sufficient length of time, and, while boiling, hermetically sealed, no form of life will make its appearance until the seal is broken; but if the same infusions are allowed to stand in open vessels, they are soon found to contain numerous infusorial animalcules. He, therefore, concludes that the germs in the infusions were destroyed by heat.

Schulze and Schwann in 1836 and 1837 passed air through red-hot tubes or strong sulphuric acid, and only the air thus treated was allowed to come in contact with the boiled infusion; the results in these experiments were the same as in those observed by Spallanzani, and the conclusions naturally the same.

1 "Omne vivum ex vivo."

2 Tyndall, in Popular Sci. Monthly, No. lxx., p. 478.

These experiments, however, only proved that the treatment to which the air was subject destroyed something that was essential to the development of life in the infusions. This something might be gaseous, fluid, or solid; that it consisted of germs, remained only a hypothesis of less or greater probability.

Schrœder and Dusch have since shown that the germs may be filtered from the air by cotton-wool. It is therefore safe to conclude that the cotton-wool excluded only solid particles, and that these solid particles were the germs from which the infusorial animalcules were generated. More recent investigation by Tyndall, Pasteur, Beale, and others has shown that the air contains living germs, while an examination of the cotton-wool shows it to have served the purpose of a filter. Secondly, Pasteur has proved that these germs were competent to give rise to living forms by simply sowing them in a solution fitted for their development. Thirdly, he showed that the incapacity of air strained through cotton-wool to give rise to life was not due to any occult change effected in the constituents of the air by the wool, by proving that the cotton-wool might be dispensed with altogether and perfectly free access left between the exterior and interior of the experimental flask. If the neck of the flask is drawn out into a tube and bent downwards, and if after the contained fluid has been carefully boiled, the tube is heated sufficiently to destroy any germs which may be present in the air which enters as the fluid cools, no form of life will appear in the contents of the flask. Although there is free communication between the atmosphere laden with germs and the germless air within the flask, contact takes place between the two only in the tube, and the germs cannot fall upwards, and as there are no currents, they never reach the interior of the flask.

It appears that all the early students investigating this subject were of the opinion that boiling a fluid destroyed all living germs, but this opinion is now advocated only by the supporters of heterogenesis.

It has been truthfully said that "the verdict in connection with spontaneous generation essentially depends on the answer which can be given to another problem. As the late Prof. Jef-

fries Wyman said: 'The issue between the advocates and the opponents of the doctrine in question clearly turns on the extent to which it can be proved that living things resist the action of water at a high temperature.'"[1]

It is even now universally admitted that boiling in water, even a few seconds, destroys *all living organisms*, but we are able to produce the highest evidence to show that certain germs resist the action of boiling water several hours and afterwards germinate readily when placed in suitable soil.

The numerous and carefully prepared experiments of Prof. Wyman are very convincing in their character, and his conclusions are entitled to the highest consideration. I am, therefore, constrained to give them here in his own words:—

"The following conclusions appear to the writer to be justified by the observations and experiments recorded in this paper.

"1st. In thermal waters, plants belonging to the lower kinds of algæ live in water, the temperature of which in some instances rises as high as 208° F.

"2d. Solutions of organic matter boiled for twenty-five minutes, and exposed only to air which had passed through iron tubes heated to redness, became the seat of infusorial life. Expr. I.–V.

"3d. Similar solutions contained in flasks hermetically sealed, and then immersed in boiling water for periods varying from a few minutes to four hours, also became the seat of infusorial life. The infusoria were chiefly vibrios, bacteria, and monads. Expr. VI.–XV.

"4th. No ciliated infusoria, unless monads are such, appeared in the experiments referred to in the above conclusions.

5th. No infusoria of any kind appeared if the boiling were prolonged beyond a period of five hours.

"6th. Infusoria having the faculty of locomotion lost this when exposed in water to a temperature of from 120° to 134° F.

"7th. If vibrios, bacteria, and monads are added to a clear and limpid organic solution, this becomes turbid from their multiplication in from one to two days. If, however, they have

[1] The Med. Record, March 23, 1878, p. 232.

been previously boiled, the solution does not become turbid until from one to two days later, and in some of the experiments not sooner than does the same solution to which no infusoria have been added."[1]

It will be observed that Prof. Wyman's seventh conclusion is in perfect harmony with the observations and practice of the general public. It is a well-known fact that when a housewife wishes to keep milk from souring as long as possible, she always boils it; or should she discover that meat or fowl, purchased for future use, sends forth the odor of beginning putrefaction, then she knows equally well that cooking it will enable her to preserve it much longer than otherwise.

The farmer, who stores up in autumn the meat to be used by his family during the following year, is occasionally annoyed by finding, after the lapse of some time, evidence of commencing putrefaction. He immediately removes the meat from the pickle and proceeds to boil the brine, also to remove from the surface the various substances which arise during the process of boiling. The meat is then returned to the original brine and the operation is frequently followed by complete success. The logical deduction in these cases is that the boiling has destroyed the low organisms, or their germs, or possibly both.

Prof. Tyndall says in regard to the action of heat on seeds: "The botanist knows that different seeds possess different powers of resistance to heat. Some are killed by a momentary exposure to the boiling temperature, while others withstand it for several hours. Most of our ordinary seeds are rapidly killed, while Ponchet made known to the Paris Academy of Sciences, in 1866, that certain seeds, which had been transported in fleeces of wool from Brazil, germinated after four hours' boiling. The germs of the air vary as much among themselves as the seeds of the botanist. In some localities the diffused germs are so tender that boiling for five minutes, or even less, would be sure to destroy them all; in other localities the diffused germs are so obstinate that many hours' boiling would be requisite to deprive

[1] Am. Journ. Sci., Sept. 1867, p. 169.

them of their power of germination. . . . . The greatest endurance that I have ever observed, and I believe it is the greatest on record, was a case of survival after eight hours' boiling."[1]

Prof. Billroth "discovered the nature and importance of certain glistening spherical bodies frequently found in infusions containing bacteria, called *Dauersporen*, or durable spores, by Cohn, although he did not not think bacteria were developed from them. Billroth demonstrated that these *Dauersporen* form micrococci in their interior, which are set free by the bursting of the envelope, and are then capable of multiplication by scission, or of lengthening into bacteria; also, that they are endowed with great vitality, and are not destroyed by freezing, boiling, or drying. He had some which germinated after they had been kept dry for eight years; and, whenever he wished to make sure of the destruction of the spores contained in his experimental liquids, he heated them to 392° Fahr."[2]

These recent investigations have thrown much light on a subject where it was greatly needed. Heretofore experimenters caused much confusion by failing to obtain uniform results.

It is certainly true that boiling destroys germs to such an extent as to render practicable the preservation of meats, fruits, etc., but nevertheless it has often failed in highly putrescible substances. The causes of failure may be inferred and satisfactorily explained by the above-mentioned facts. Again, these observations were made by men not unknown to fame, and it should not be forgotten that Pouchet was an earnest advocate of spontaneous generation. The failure of the earlier observers to detect living organisms in water, which had been previously boiled, was probably due to the comparatively low powers used by them in their microscopical examinations.

The discovery of living germs in fluids, previously boiled, has failed however to prove the correctness of the opinion held so long ago by the ancients, and is now satisfactorily explained by

[1] Popular Sci. Monthly, No. lxxi. p. 596.
[2] Ibid. No. xxxiv. p. 401.

the recent discoveries. Observation and experimentation have confirmed the fact that all living bodies take their origin from pre-existing living matter, and further, that in every instance where the unaided eye can follow the process of germination, the germ is produced from a living parent or parents. The fish culture of the present day furnishes a beautiful example of this, and the same may be said of fruit, grain, and grass. In fact, examples of this kind are universal, and no exception to the rule can be cited either in the animal or in the vegetable kingdom.

Is it not therefore rational to suppose that the laws governing the generation of the higher orders of living beings hold also in the creation of the low organisms? Is it rational to imagine that in the former case all forms of life take their origin from living germs, and, in the latter, to maintain that lifeless matter spontaneously assumes the living state? The answer to these questions may be found in the fact, as I believe, that all forms of living matter arise from pre-existing living matter.

Having considered some of the salient points of the question of spontaneous generation, a knowledge of which enables us to comprehend more fully "The Germ Theory of Disease," I shall now raise the question, What is a germ?

The term germ can be properly applied to any particle of living matter, possessing the power of germinating when placed under circumstances favorable to this action. These germs vary in size, some being so large as to be readily perceived by the unaided eye, and others so small as to require the highest powers of the microscope to detect them.

Prof. Tyndall has shown that the highest powers often fail to indicate the existence of minute particles, germs, etc., although they may be readily seen in the atmosphere by the aid of a beam of sunlight. Any attempt at a description of the varieties of germs, their peculiarities, methods of multiplication, and the circumstances attending their existence, would require too much space here. Therefore let it be remembered that "the living particle which sprouts from a cell of the adult plant or organism, and is then detached, may be called a *germ*, as well as the living particle formed in the ovum, or the living matter in the

ovary from which the new being is evolved. . . . . So that a *germ is but a particle of living matter, which has been detached from already existing living matter, and this living matter came from matter of some sort which lived before it.*"[1]

I shall now mention a few varieties of germs. A cell of epithelium consists of a germ, or germinal matter, surrounded by formed matter which was once in the germinal state. In the same way the oval yeast particle consists of a germ with an envelope of formed material.

It will now be readily seen that germs, or germinal matter, exist in every organ and tissue of the living body, and to distinguish these from disease germs I call them "normal germs." The planting of normal germs in what is familiarly called "skin grafting," consists essentially in a transfer of living protoplasm from healthy integument to the surface of an ulcer. In watching the progress of these cases I have frequently witnessed interesting phenomena. It is the rule to allow the dressing applied immediately after the application of the graft to remain undisturbed about forty-eight hours. At the expiration of this time, the dressing is removed and the ulcer cleaned, when it is frequently discovered that every trace of the grafts so recently applied has entirely disappeared, or at least is not discernible to the unaided eye. However, after a few days there appears, on the site of each graft, a grayish-white speck which rapidly increases in size, and serves as a new point of cicatrization. In what did these phenomena consist? The germ theory affords a satisfactory explanation of the question. The formed material had undergone putrefactive solution, and the germinal matter having found a soil congenial to its wants had taken root to bring forth a thousandfold. The germ theory of disease presents here for examination the following questions: 1. Do the phenomena of certain diseases depend on the propagation in the system of minute living organisms having no part in its normal economy? 2. Do these organisms arise from germs? 3. How do they find their way into the system? The first question has been

[1] Beale on "Disease Germs," London, 1872, p. 10.

carefully studied and thoroughly discussed by many of the most eminent physicians and surgeons of Europe from both the pathological and biological points of view, and even analogy has been called to its assistance.

However, the brief character of this *résumé* does not permit me to present anything beyond a few of the more important facts and discoveries.

"Dr. Beale was the first who pointed out the existence in clear and translucent vaccine lymph of minute particles. The existence of these he demonstrated by means of the microscope, and expressed the opinion that the activity of the fluid depended on the presence of these particles. M. Chauveau experimentally demonstrated that the vaccine virus does consist of minute particles; and his observations have been verified by Dr. Burdon-Sanderson."[1] "These particles have often been termed *débris*, and have been regarded as quite unimportant elements of the lymph. To them, however, the active properties of the lymph are entirely and solely due. And I should be no more inclined, in the absence of the most positive evidence to the contrary, to regard the fluid portion of the vaccine lymph as the active material, than I should be to assume that the fluid in which the spermatozoa were suspended was the fertilizing agent, and that the spermatozoa themselves were merely epithelial *débris*, and quite unimportant; or to infer that the fluid in which the yeast fungi or bacteria were growing was the active agent in exciting fermentation while the actually growing, moving, and multiplying particles were perfectly passive."[2]

"Chauveau showed that the active particles subsided after forty-eight hours, and that no effects were produced by inoculating the albuminous supernatant fluid, while the full effects were produced by vaccinating with the deposit."[3]

Do these facts justify the conclusion that the first proposition is proven? I have satisfied myself by repeating these experiments that the facts are as previously stated.

1 Maclagan on "The Germ Theory," p. 7.
2 Beale on "Disease Germs," London, 1872, p. 144.
3 Ibid. p. 146.

Dr. L. A. Stimson says of these living organisms: "It is probable that their *rôle*, as far as disease is concerned, is as follows: While they have no power in themselves to excite disease (*diphtheria, vaccina, septicæmia, typhoid fever*, etc.), they are able to absorb the poison (ferment ?) which is capable of producing it, to "fix" it, as it is termed, and to give it up to any tissue with which they may come into contact, acting thus as carriers of contagion: then, after the abnormal process has been commenced in the body, a change is brought about in the tissues which renders them suitable for the rapid growth and multiplication of the bacteria, which, in turn, augment the change in the tissues, and thus there is formed a vicious circle, the consequences of which are too often fatal. Any agent which destroys the life of the bacteria, or prevents their multiplication, breaks this circle, and renders a cure possible."[1]

Prof. Dalton says: "The process of putrefaction is accomplished by the growth and multiplication of a microscopic vegetable organism, somewhat analogous to that by which fermentation is excited in saccharine fluids."[2]

Prof. Liebermeister, in discussing the causes of infectious diseases, makes use of the following language: "As an argument in favor of the view that infectious diseases are produced by low organisms, it will not be without significance to regard the facts which led in former times to the unexpected acceptance of parasitismus as the cause of disease. I only call attention to the numerous skin diseases produced by fungi, to the trichina disease, to the examples of mycosis intestinalis, which have been observed with increasing frequency in later times, as well as to the development of fungi in numerous other affections. Scabies, so long as the itch mite was unknown, was regarded as the prototype of a purely contagious disease, and even after the discovery of the mite there have been endless discussions, until finally this parasite, which is so easily detected, was recognized by all as the sole and satisfactory cause of the affection. The

[1] Popular Sci. Monthly, No. xxxiv. p. 404.
[2] Human Physiology, sixth edition, p. 83.

fact that this disease is now stricken from the lists of contagious diseases, and reckoned among the parasitic, shows that we may, perhaps, expect further changes among infectious diseases. In this connection, however, there are facts of considerable importance, which have been furnished by recent investigations into the nature of many contagious diseases in animals and plants.

"The contagious diseases of the silk-worm, which have been a source of so much danger to the silk-worm culture, have been proved to be parasitic, and the history of the development of the parasite has been followed pretty thoroughly. In flies and many other insects, we have known similar epidemics of a parasitic nature to have taken place. The epidemics and contagious diseases of the higher classes of cultivated plants, such as the potato disease, the grape-vine disease, the ergot of grain, and others, all are derived from fungus growth. The question, too, on which for a long time opinions were divided, as to whether the fungus was the cause or only the consequence of the disease, has been answered by botanists with unanimity. Where the development of the fungus had been thoroughly examined, they reported that it was the sole and sufficient cause of the disease. It is clearly evident, too, that the further the progress of investigation advances in human pathology, and the more frequently low organisms are shown in diseases, the more prominently will this question urge an answer."[1]

In several of the contagious diseases, low organisms have been observed and more or less accurately described. Although it must be admitted that their exact relation to the disease has not been fully determined in the majority of cases. It has, however, been satisfactorily shown by Prof. Cohn, of Breslau, and other excellent authorities, that there are several species of these low organisms, and that the bacteria which are found in decomposing and putrid fluids are different from those observed in disease. Dr. Sanderson has said "all microzymes are not contagia, but all contagia may be microzymes." This brings us

[1] Ziemssen's Cyclopædia of Pract. Med., vol. i. p. 12.

to the pertinent question, What is a contagium? Liebermeister defines it thus: "It is usual now to speak of *contagium* as a specific excitant of disease, which originates in the organism suffering from the specific disease; while *miasm*, on the other hand, is used of a specific excitant of disease, which propagates itself outside of, and disconnected from, a previously diseased organism."[1]

Maclagan says: "A contagium is a morbific agent, which is propagated in, and given off from, the bodies of the sick, and is capable, when received into a susceptible healthy body, of producing in that body a disease similar to the one during whose course it was formed."[2] He further adds: All that we know regarding contagium is: 1. that it consists of minute solid particles; 2. that these particles are probably organized; 3. that in chemical composition they so closely resemble the fluids in which they occur, that the chemist fails to detect even their presence; and 4. that they are so very minute that the highest powers of the microscope fail to give us definite information regarding their nature, or even their existence."[3]

We will now give our attention to the third question: How do germs find their way into the system? They may gain admission by immediate contact, through the agency of carriers, the air we breathe, the drink we take, or the food we eat. These are the recognized methods for the propagation of contagious, miasmatic, and septic diseases; and the germ theory seems to possess a special applicability to them, but I shall from this point devote my attention entirely to the relation of the theory to wounds. It will be observed as we progress with this inquiry that the oldest recorded opinion ascribes to the atmosphere a more or less powerful action on wounds. It further appears that this action was supposed to be due to the physical properties of the air, heat, cold, moisture, or dryness.

Hippocrates refers especially to the action of cold in the following: "Cold pinches ulcers, hardens the skin, occasions

[1] Ibid. p. 25.
[2] The Germ Theory of Dis., p. 5.
[3] Ibid. p. 31.

pain which does not end in suppuration, blackens, produces febrile rigors, convulsions, and tetanus."[1]

The opinion here expressed was firmly and generally maintained by the profession until the early part of the present century. Thus during the first eighteen hundred years of the Christian era, we find surgeons almost universally attributing all surgical complications to the action of cold. The laity during this period learned also to regard cold as the greatest enemy of the wounded, and the impression then made on their minds has not yet been fully removed, as is now frequently shown by their anxious questions in regard to protecting wounded surfaces.

This opinion, although general, was not fully shared by Galen who, eighteen hundred years in advance of his times, declared that the air often becomes injurious and dangerous in consequence of the heterogeneous substances for which it serves as a vehicle.

Celsus, who had carefully studied wounds, tumors, ulcers, etc., was able only to reproduce the precepts put forth by Hipocrates, and like him, recognized the necessity of immediately closing wounds to protect them against the action of heat and cold. "In the year 160, Galen reproduced the ideas of Hippocrates and Celsus, and like his predecessors only considered the physical qualities of the air. According to him the air might be dangerous by its temperature, its degree of humidity, or dryness; he finally added a very important fact that the air becomes noxious in consequence of the heterogeneous substances it holds in suspension. One should not be surprised by seeing him also attentive to the protection of wounds from contact with the air, and in finding him so enthusiastic for treatment with greasy bodies, or the cerate which bears his name."[2]

A distinguished surgeon of the fourteenth century, Guy de Chauliac, busied himself in endeavoring to perfect a system of treatment whereby he might protect wounds against the physical action of air.

[1] Aphorisms, Sec. V. No. xx.

[2] De l'action de l'air sur les plaies, par le Dr. Caury, p 5.

In the sixteenth century Ambrose Paré engaged in a similar work, imbued with the same idea—the necessity of protecting the wound against the physical action of the air. Paracelsus, who lived in the middle of the sixteenth century, advised absolute cleanliness of the wounds, and the removal of all substances which could possibly irritate them, and is supposed to have admitted the agency of the air as a carrier of foreign substances.

In 1612, Magatus, Professor at the University of Ferrare, gave the following rules for the treatment of wounds: "It is necessary," said he, "to avoid with great care: 1. The contact of the air because it irritates the wound; 2. Movements, which might produce derangement of the work of agglutination; 3. The removal of the pus, which, far from constituing a bad substance, is the best of topical applications, since it is furnished by nature."[1]

The views of Magatus were endorsed in England by Wiseman, and in France by Billroth, during the same century. "In the eighteenth century Pibrac defended the same principles; fearing above all the action of cold in wounds, he advises infrequent dressings; he proposes even, with a view to prevent exposure of the parts to the air, to renew only the external soiled dressings and to leave untouched the charpie which is in immediate contact with the wound." . . . . J. L. Petit, who lived from 1674 to 1760, and who was one of the greatest surgeons of his epoch, feared much the action of air on wounds, and thus he recommended to avoid contact with it when it was possible. . . . . In 1766, McBride published his memoirs on the respective properties of antiseptics, and announced first this precept that the air is the principle which forms the cement or bond of union of all the elemental parts of bodies, the preservation of the stability and good state of the body, depending on that which prevents the escape of this air. He also professes that the precaution to cover accurately all kinds of solution of continuity has the aim to prevent the escape of air which enters into the constitution of all the parts, and which bears on all the

[1] De rara Medicatione Vulnerum, p 61.

organs, in concert with the other elements of the body. For himself he did not recognize suppuration as due to any other cause than the escape of air, and it is nothing else than incipient putrefaction.

Jean Falcon thinks air may prevent the healing of a wound in two ways: sometimes by reason of its quality and sometimes by reason of its substance. He also refers to the drying up of the blood and the gelatinous humor, which are the liquids, by means of which the union and the agglutination of the lips take place. He further adds that in certain cases the air acts mechanically by preventing a perfect approximation of the lips of the wound."[1]

It will be readily seen from the new theories advanced in regard to the action of the air by McBride and Jean Falcon that they were not satisfied with the correctness of existing ones, but wished for something better.

In 1771, A. Monro, a pupil of Cheselden, became an advocate of the aerophobic ideas of his times.

John Hunter declares that the air is not the cause of suppuration in wounds. Some other English authors asserted that wounds suppurated in vacuo the same as in the open air.

John Bell combated the ideas of Hunter and regarded the air as possessing irritant properties, and recommended the immediate closure of wounds for the purpose of excluding air. During a discussion, which took place in the "Paris Academy of Surgery" about the year 1825, on the following question: Apprécier l'influence des choses nommées non naturelles dans les maladies chirurgicales," the following attributed to the air an injurious action on wounds, viz., Sancerotte, Didelot, Lafflige, Champeau, Campe, Lombard, and Boyer. Larrey was a strong advocate of the aerophobic ideas, but he was opposed by Blondin and Lisfranc. The illustrious Delpech performed tenotomy subcutaneously for the first time on May 19, 1816. The object, which he sought to accomplish, was the protection of the wound in the tendon from the injurious action arising from contact with

[1] Ibid. p. 8.

the air. His success in this effort aroused in others a spirit of emulation, and we find Dupuytren performing myotomy subcutaneously in 1822.

Stromeyer modified and improved Delpech's operation in 1831, and Dieffenbach published in the *Archives générales de Médécine*, of 1835, an account of numerous and remarkable successes which he had obtained. Duval, Bouvier, and Jules Guérin contributed to perfect and popularize subcutaneous operations.

Dieffenbach contended earnestly in favor of the noxious action of the air on wounds against Malgaigne, Ollivier, and Velpeau, and finally had the satisfaction of partially convincing them of his views. Jules Guérin, in this discussion, brought forward a large number of cases in which he had operated subcutaneously, which had not been followed by either inflammation or suppuration, and in which recovery had been remarkably rapid. He further called attention to the fully admitted fact, that in every case of tenotomy which was not performed subcutaneously, the operation was always followed by inflammation and suppuration. Bouley, Renault, and Bouvier admitted that the influence of the air might retard cicatrization and render it difficult and dangerous.

"It was reserved for Prof. Bouisson to enlarge on the importance of the action of the air on wounds, and to put forth, in this respect, ideas which contain, in brief, all the actual doctrine of the nosocomial intoxication."[1] This idea was suggested in the year 1858. "In 1861–62 the question of the influence of the air on wounds came up before the Academy of Medicine on the occasion of a discussion relating to the hygiene of hospitals, during which Piorry, Larrey, Duvergie, Gosselin, and Michel Lévy expressed their opinions on the action of the nosocomial atmosphere. These honorable academicians no longer considered the nosocomial air as the agent of the inflammation and the suppuration of wounds, but they recognized it as capable of determining poisonous accidents, either by its absorption directly through the lungs or through the wounds themselves."[2]

[1] Ibid. p. 17.

[2] Ibid. p. 27.

This atmospheric condition, so frequently referred to in these times, and so often recognized in overcrowded hospitals, was also known to many of the older physicians. This air of the wards, to which Delpech, in 1815, had called attention on the occasion of an outbreak of hospital gangrene, has been designated by the name of *nosocomial malaria* by Giraldes.

We have attempted to set forth the prevalent ideas among eminent surgeons, from the time of Hippocrates to the present, in regard to the action of air on wounds. We now find it safe to assert that it has been generally admitted by those most competent to form a correct opinion on this subject, that the air does exert an injurious influence on wounds. In fact, I am not aware that any surgeon of our times is willing to deny it. Certainly the universal success which has attended the performance of subcutaneous operations, the absence of inflammation and suppuration, the great rapidity with which its wounds heal, and the almost complete absence of all surgical complications, surely speak in language which we are compelled to hear and heed. Again, the freedom with which we use the invention of Dieulafoy, the impunity with which we pass these needles into visceral organs, cannot fail to teach us an important lesson. Lastly, let us reflect on the vast difference in success which attends the management of a simple and of a compound fracture. The simple, or even comminuted fracture, is rarely attended with danger to the life of the patient, although in many instances there are extensive subcutaneous lacerations, but as long as the principal blood-vessels are still intact, little or no anxiety is felt by the surgeon for the safety of his patient.

How different are the views taken by the surgeon in regard to the safety of his patient in cases of compound fractures, and experience has taught us here to be very cautious in our prognosis. *In fact we have learned that the contact of the air with a wound is always attended with danger.* We recognize it, we admit it, we see it, we feel it. How does the air exert its injurious influence on wounds? We have already the following theories advanced in explanation of its action :—

1st. That it depends on its physical qualities, viz., cold, heat, moisture, or dryness.

2d. That it is due to foreign bodies for which the air serves as a carrier.

3d. That the air acts mechanically by preventing the perfect approximation of the lips in incised wounds.

4th. That the air contains germs, which being received into wounds are found to generate living organisms; that the presence of these organisms in the wounds gives rise to inflammation and suppuration, and even in some cases to the septic diseases which are so frequently found as complications of wounds, especially in over-crowded hospitals and other unfavorable locations. In regard to the first theory advanced with respect to the action of air on wounds by virtue of its physical properties, it is scarcely necessary even to mention the reasons which probably forced the surrender of the ancient idea, since very little, if any, importance is now attached to it by surgeons. In fact, the practice of surgery of the present day is strongly antagonistic to the idea that cold is greatly to be feared. We now obtain excellent results in the treatment of wounds by the application of cold, or even of ice; the latter should certainly be classed among our best antiseptic remedies. The second proposition is undoubtedly correct, although the nature of the foreign bodies was not understood at the time the theory was proposed. The third theory possesses little practical importance, and it never sufficed to explain the injurious action of the air on wounds in the large majority of cases or even in a single case satisfactorily when the surgeon had performed his duty well.

The first theory has been proved *erroneous;* the second is a *brief statement of a fact;* the third contains *very little* of importance. The fourth furnishes the necessary *explanation,* or, in other words, the fourth theory admits all that is set forth in the second, and at the same time designates in a specific manner the character of the foreign bodies and their *modus operandi.* Pasteur fully demonstrated that "any liquid, however putrescible in the ordinary condition, may become incorruptible when you have killed all the germs it contains, and when it is protected

from contact with those of the air. The germs in suspension in the air suffice to provoke the apparition of living beings when they are sown in a substance rendered incorruptible. . . . To-day the great majority of learned men have rallied to the doctrine of Pasteur, because the study of germs has not only a theoretical interest, but also considerable practical importance; therefore, thanks to their researches, be they chemical or microscopical, they have enabled us to recognize, that, among all other detritus, there exists in the atmosphere the germs of vegetables and the eggs of animals, infinitely small, all living forms which develop themselves at the expense of their surroundings, and which produce in nourishing themselves by these aliments, the peculiar decompositions which are designated under the names of fermentation and putrefaction. Hygiene and pathology are only benefited by these interesting studies, because a new horizon has been opened before them; it has permitted them to seek the action of these invisible parasites, the causes of the great destructive plagues which have decimated humanity."[1]

It must be generally admitted that the process of putrefaction is accomplished by the growth and multiplication of microscopic vegetable organisms, frequently designated as *bacterium termo*, although the multiplicity of names applied to these and similar organisms has certainly led to much confusion.

Dr. Burdon-Sanderson says: "For these organisms, or rather for the group of organic forms which they represent, I proposed in my former paper the term 'microzymes,' the only name by which they were then and are still known to naturalists (*schizomycetes*), being too long for common use. Of the legion of observers who have contributed to the literature of the subject during the last few years, most have used Hallier's word, *micrococcus*. The surgical pathologists, on the other hand, have devised words for themselves. Klebs, in his book on gunshot wounds, introduced the term *microsporon septicum*. Hueter, in his studies on surgical fever and other secondary traumatic

[1] Ibid. p. 32.

affections, has used the word 'monads;' and lastly Billroth has entitled the massive folio which he has lately published on the same subject, *Coccobacteria Septica*. In the existing confusion of terms, it is probably best to continue to employ those words which express most simply the forms of the things referred to.

"Micrococci it is convenient to call either by that name or simply spheroids; the words dumb-bell, chain, and colony or zooglea, may also I think be advantageously retained as preferable to the terms *diplobacteria*, *streptobacteria*, and *gliobacteria*, which Billroth proposes to substitute for them. In addition to these, the word *mycosis* may be conveniently used to indicate the infiltration of a living tissue with micrococci."[1]

While engaged in the consideration of these organisms in connection with wounds and the septic conditions which are found so frequently complicating them, I desire to call your attention to the following by F. Steudenen: "Pyæmia and septicæmia take the first place among the few infectious diseases in which a vegetable organism, as a living virus, has been examined and demonstrated in a scientific manner. To Klebs belongs the honor of having discovered this organism, and of having followed out with the greatest accuracy the manner of its propagation and action, and also of having proven by his experiments the correctness of this view. . . . . Klebs found by the examination of the secretions of wounds, vegetable organisms in varying quantities in the thick creamy pus as well as in the ichorous; being, however, extraordinarily numerous in the latter, and never entirely absent from the former. . . . . He also found, by further examination, these organisms in the form of zooglea settled on the granulation-tissues, and on ulcerating cartilages. He followed their entrance into the intracellular spaces of the connective tissue where they excite inflammation and suppuration; the same results are also produced by their entrance into the medullary substance in traumatic osteo-myelitis. Here he observed their destructive influence on the vessels, which, in consequence of the penetration

[1] Reports of Med. Officers of Privy Council, N. S. No. iii., 1874, p. 12.

of the walls, there is formed an adherent or obstructing thrombus."[1]

Again in regard to these organisms it is known that filtration of putrid fluids through porous porcelain under pressure, deprives it simultaneously of its offensive smell, poisonous action, and power of generating bacteria; thus may the most virulent septic liquid be deprived of its poisonous properties. I also fully agree with Prof. William Roberts who says: "We know further, from the evidence I have laid before you, that decomposition cannot take place without bacteria, and that bacteria are never produced spontaneously, but originate invariably from germs derived from the surrounding media. . . . . We should probably differ less about antiseptic treatment if we took a broader view of its principles. We are apt to confound the principle of the treatment with Lister's method of carrying it out. The essence of the principle, it appears to me, is not exactly to protect the wound from the septic organisms but to *defend the patient against the septic poison*."[2]

The diseases arising from septic poison may be truly said to be the opprobrium of surgery, and further, that the chief success in the management of wounds has always, and must always continue, to depend principally on the ability of the surgeon to protect his patient against this poison. Let us now examine the *successful treatment of thirty-five consecutive amputations one hundred years ago*, by J. Alanson. The dressings were changed no oftener than was necessary to secure perfect cleanliness. In a word, the surgeon with great care and nicety aimed at primary union, and his success was all that could be desired. It is also said, "Alanson was fully alive to the dangers of foul air of hospitals, as shown by the fact that one patient was removed from the infirmary during a severe attack of erysipelas, and, after being bathed and supplied with new clothing, was placed in a new building near at hand."[3] Here we find, more than one

[1] Sammlung Klinische Vorträge, No. 38, p. 300.
[2] Med. Times and Gazette, August 11, 1877, p. 138.
[3] The Med. Record, vol. xi. p. 756.

hundred years ago, a surgeon applying the antiseptic treatment, and fully aware of the danger of exposing a wounded surface to the vitiated air of a hospital.

The only advantage to be gained by what is called *The Open Method of Treatment of Amputations* is wholly due to a diminished liability on the part of the patient to become contaminated with the septic poison, and the phrase "diminished liability" must here be received in a limited sense. While it may be an improvement over the ordinary closed method, it is certainly far from being perfect. The open method may succeed—will in a comparatively pure atmosphere, but in an overcrowded hospital, where the air is badly vitiated, it should certainly give way to some better system. Let us glance at the advantages of this open method.

1st. In this method *there is no probability of mechanically sealing up putrescible fluids within the freshly cut surfaces of the flaps, as is often done by the closed method.*

2d. Since nearly all secondary wound complications depend on the absorption of putrefactive substances or their agents, it follows, that in the same ratio that you prevent this absorption you avoid the appearance of these diseases.

I will also refer to a favorite dressing in France, *The Cotton Wadding*, which has received the endorsement of the Paris Academy of Surgery. This method of treatment is based on the idea that the air contains germs which may be kept from coming in contact with the wound, and by these means the patient may receive the required protection.

The application of ice in cases of severe contuso-lacerated wounds is a favorite remedial agent with many surgeons. Billroth speaks very highly of it. He applies it in cases of injuries of the extremities, not only to the wound itself, but along the limb, above and below it. He allows the ice to remain continuously applied until the laceration has healed. He informs us that the wounds treated in this manner *do not suppurate;* that they are very rarely attended with cellulitis, or any other indication of septic infection. The explanation of these facts is comparatively easy by the aid of the germ theory. We

know that all living organisms are killed or rendered torpid by exposure to cold, and that germs do not germinate in ice. For these reasons we may expect a certain degree of benefit to be obtained by the industrious use of ice-water; but the direct and continued application of ice, or ice-bags, will be found much more advantageous in a majority of cases. There are some cases of amputations and other wounds which may be advantageously treated by irrigation, providing proper caution is used to make the irrigation thorough and absolutely continuous. I would suggest, however, that the water used should contain antiseptics; although the force with which the fluid is thrown on the wound will very strongly tend to wash away organisms and germs.

In *the closed treatment* of amputations the flaps are closed after the performance of the operation, or, more correctly speaking, immediately after the cessation of all oozing, although some surgeons favor leaving it open a little longer to allow glazing to take place, which is a condition depending on the drying of the exudation on the surface of the wound. It will be observed that Alanson *even by this method* obtained excellent results, but it should be remembered at the same time, that he made the treatment, by extraordinary care, really antiseptic, at least as nearly so as human skill could under the circumstances. I am, however, inclined to think that even he had fewer obstacles to overcome in his time than the surgeons of the present day. His operations were performed prior to the use of anæsthetics, and consequently he probably found less trouble in completely arresting hemorrhage than we now contend against. The violent struggling of the patient during the operation, I think, would probably cause all vessels to bleed instantly that would bleed at all, and consequently the surgeon would arrest all hemorrhage before leaving his patient. In this method of treatment the great danger, to which I desire to especially call attention, is the oozing which occurs after the closure of the flaps. We now always operate while the patient is under the influence of an anæsthetic, the principal arteries are promptly ligated, the tourniquet is removed; if any arterial branches

should be found to bleed, they will receive promptly the surgeon's attention, but the anæsthetized condition of the patient does not favor hemorrhage. The flaps are closed; reaction commences after the lapse of a longer or shorter period; then oozing within them; circumstances which are in the highest degree favorable to septic poisoning. There is a putrescible fluid, atmospheric air loaded with germs, a proper degree of heat, and to aid these conditions still further, pressure from without.

I question whether human skill can devise more favorable conditions for the speedy germination and certain introduction of this septic poison into the body of a patient. I might very properly mention here other important objections to, and defects in, this method of treatment; but I will merely add that it is *certainly not* the *best* method of treatment which can be adopted in the *vitiated* atmosphere of a hospital.

The first publication in regard to *Lister's Antiseptic Treatment of Wounds* was made by Prof. Joseph Lister in the *Lancet*, March 16th and 23d, 1867. It is not necessary for my purpose that I should here enter into a detailed report on the materials used, and their mode of application, but as Assist.-Surg. A. C. Girard, U. S. A., has said: "The only thing which concerns us here is the indisputable fact that there are germs or ferments in the atmosphere which will produce putrefaction in wounds, and that by preventing their ingress we can in most cases avert the complications which cause the greatest fatality in surgery. This is the key to Lister's system."[1] I feel that it is impossible for me to bring the merits of this treatment before you in a more forcible manner than has been done by Dr. Girard in his excellent report, to which I have already alluded; and I only regret that it has not been in the hands of every surgeon in this country.

I am thoroughly convinced that he who reads the arguments in favor of this theory as they are detailed to-day in the German and French literature, cannot fail to be convinced of its value,

[1] Surg.-General's Office, Washington, D. C., August 20, 1877, p. 1.

unless he refuses to be convinced by any argument that he finds himself *unable to refute*. Let us now examine further Dr. Girard's statements. He says: "During a sojourn abroad last winter my attention was particularly drawn to this innovation in surgery, as it had been introduced on the European continent but two years, and was the almost exclusive topic of conversation of the surgical profession there. It happened that my first intercourse was with some of the most decided and renowned opponents of the system, and I became acquainted with all the objections to it before I had witnessed its advantages and benefits. I received therefore the glowing accounts of Lister's disciples with an incredulous ear, and it was only by travelling from one 'Lister Hospital' to another, that belief in its superiority forced itself upon me. I became convinced that if it is not the only proper wound-treatment, it is the safest one, and renders conservative surgery possible beyond what had ever been believed. It would take volumes to describe all I witnessed, and I cite but a few examples. Who, before this, would have fearlessly opened the knee-joint for suppurative arthritis, as I saw done under the 'spray,' the patient recovering in a few days with a sound joint? Who would have expected an ovariotomy with general adhesions, in a woman seventy-five, to heal in eight days without a symptom of reaction, or a laparotomy for the liberation of an incarcerated peritoneal hernia in a moribund patient, healing in six days, or a resection of the ulna in nine days. . . . . Hospitals which had been in use for centuries and had become hot-beds of infection, where the majority of operations formerly were followed by pyæmia, gangrene, and erysipelas, where everything had been tried to combat these evils, where treatment 'open,' 'occlusive,' by 'immersion,' compresses of chlorine water, carbolized water, even Lister's 'gauze' and 'paste' had failed, become entirely free from these complications as soon as Lister's system with all its precautions had been introduced. Prof. v. Nussbaum, Surgeon-General in the Bavarian Army, told me that formerly he operated in his hospital with the greatest reluctance, as nearly every case was sure to be followed by grave accidents, even the opening of a

panaritium or the amputation of a finger, would cause pyæmia and death; wounds granulating in the most healthy manner, as soon as brought into his hospital, would become gangrenous and the patient would die, when a few days before he appeared to be on the eve of entire recovery. Now everything is changed. While during sixteen years in which he had charge of the Munich General Hospital pyæmia never failed a single month to make its appearance, until at last it seized eighty per cent. of the patients, since the introduction of Lister's system it has absolutely disappeared. The same is the experience of Professor Volkmann, of Halle."[1]

The limited space of this treatise does not allow me to enter more fully on the subject of Lister's treatment of wounds; neither does the object which I have sought to accomplish require it. My principal aim has been to call the attention of the surgical profession especially to these facts, viz:—

1. That there are certain germs in the air, more particularly in the atmosphere of over-crowded hospitals, which, if permitted to enter wounds, give rise directly to living organisms, inflammation, and suppuration; and indirectly to all septic conditions which are found as wound-complications.

2. That the successful management of wounds depends principally on the ability of the surgeon to keep the wounds, under all circumstances and at all times, free from germs and living organisms; and therefore the value of any method of wound-treatment depends primarily on the degree of antisepsis which can be obtained by it.

3. That the occasional discovery of a few bacteria in a wound, which has been treated antiseptically, does not disprove the fact that these bacteria arise from germs; but may be satisfactorily explained in a variety of ways, especially by the existence of germs which have not been destroyed by the means employed.

[1] Ibid. pp. 2, 3.

CHAPTER VII.

THE APPLICATION AND MANAGEMENT OF VARIOUS FORMS OF AFTER-TREATMENT. LISTER'S ANTISEPTIC. THE MATERIAL AND ITS PREPARATION. GUERIN'S COTTON WADDING. O'HALLORAN'S OPEN METHOD. CALLENDER'S MODIFIED ANTISEPTIC. MARKOE'S MODIFIED ANTISEPTIC. GAMGEE'S DRY AND INFREQUENT DRESSINGS. HEWSON'S EARTH TREATMENT. WATER DRESSINGS. MANAGEMENT OF THE PATIENT DURING THE AFTER-TREATMENT.

It is even universally admitted by the surgical authors, who have not yet employed the antiseptic method, that no system of wound-treatment has ever given any better results; whilst those surgeons, who have abandoned all other methods, and now adhere *strictly* to Lister's system of wound-treatment, are enthusiastic in its praise, and confidentially declare that no other practice gives the same degree of safety to their patients. It is, therefore, unnecessary to enter here into any details intended to illustrate the superiority of this form of treatment. The Lister system of wound-treatment as now perfected meets in every particular the demands of the germ theory, and this is not true of any other form of dressing which has ever been recommended or employed. In all cases where this system has been employed in the treatment of wounds, it has been followed by complete asepsis; if otherwise, the surgeon himself, or, the material employed, must be held responsible for the results, and not the method. Dr. Robert F. Weir, of New York, says: "The chorus on this point is unanimous among surgeons who have sucessfully used it. Hagedorn, of Magdeburg, says that in every failure the surgeon himself is to blame, and not the method; and Lindpaintner, representing the experience of Munich with nearly a thousand cases treated antiseptically,

states that it must be considered a precept that the minutest directions must be followed, and that he who does not get the result (desired) must certainly have made some mistake. This opinion is reiterated by all who have achieved success by the method, and the number of such is already large and increasing. A second condition, which really should have come first, is that they who use the method should at least provisionally accept the theory on which the dressing is based; they should, so to speak, act as if they saw germs on everything. This, however, is not so imperative as the one just spoken of. 'For,' remarks Lister, 'those who are unwilling to accept the theory in its entirety, and choose to assume that the septic material is not of the nature of living organisms, but a so-called chemical ferment destitute of vitality, yet endowed with the power of self-multiplication . . . such a notion, unwarranted though I believe it to be by any scientific evidence, will, in a practical point of view, be equivalent to the germ theory, since it will inculcate precisely the same methods of antiseptic management. It is important that this should be clearly understood.'"[1]

Let us now turn from these introductory remarks to the consideration of the various articles required for the proper application of the antiseptic dressing to amputation wounds. The only germ-destroying agent employed by Lister during the performance of an amputation is the carbolic acid. There are required three acid solutions, carbolized catgut ligatures, metallic sutures, protective, Mackintosh, and antiseptic gauze. The *three carbolic acid solutions* should be carefully prepared and properly labelled before the commencement of the operation. The solution commonly called 1–30, and which is intended for use with the steam atomizer should be filtered in order to avoid the stoppages in the delivery tube, which will otherwise occur. This 1–30 solution when mixed with the steam should form a spray of the strength of 1–40, and it will therefore be observed that the strength of the solution intended for use with the atomizer should depend on the atomizer itself. The 1–20 solution is employed in cleansing

[1] New York Med. Journ., vol. xxvi. p. 563.

the operator's hands, the parts contiguous to the point at which the amputation is to be performed, while all the instruments, drainage-tubes, and sponges which are to come in contact with the wound during the operation, ought to be kept in this solution at least half an hour before they are used, in order to render them thoroughly antiseptic. In my own practice of antiseptic surgery, I *very seldom employ* the sponge, and greatly prefer the use of the antiseptic gauze, after having dipped it in the 1–40 solution for all the purposes for which others commonly employ the sponge. The gauze possesses the advantage of being always at hand, and antiseptically prepared, and is never used but once and then thrown away. The 1–40 solution is employed in washing the fresh wounds, and may be injected through the drainage-tube after the closure of the flaps and the introduction of the metallic sutures. The surgeon after having carefully cleansed his hands with the 1–20 solution, will find it advantageous if he anoints them with an oleaginous mixture, which should contain one part of the acid to ten of the oil. The application of this mixture will diminish the benumbing, irritating, and roughening effects of the acid. All the aqueous solutions of carbolic acid, but more particularly the 1–20, will be improved by the addition of about six ounces of glycerine to each gallon of water. The glycerine is an excellent solvent of the acid, and consequently serves to hold it in solution, and at the same time renders it somewhat less irritating.

Carbolized Catgut Ligatures.—These are the only ligatures which should ever be used in the practice of antiseptic surgery. The ligatures having been placed on the arteries in the usual way, then their ends are cut close to the knots which require no further attention from the surgeon. These ligatures are now made so satisfactory that no better means for the control of hemorrhage can be desired, and even torsion of the arteries seems likely to be entirely abandoned.

Drainage Tubes.—Black rubber tubing is the material most frequently employed for these tubes, and will be found varying from the size of a small quill to that of the little finger; and it should be perforated with suitable openings which serve for the

admission of the wound secretions. The number and size of the tubes employed in any given case ought to depend on the wound itself. The surgeon in every instance should employ a sufficient number of tubes to drain the wound effectually; but no more, since any unnecessary separation of the flaps can only act injuriously on the healing process. Both ends of each tube should open outside of the wound, and they are best secured in their places by passing fine cambric needles which have been properly carbolized through their distal extremities as close as possible to the integument, and after their introduction the points should be snipped off with bone nippers. These needles, having been properly introduced, will now be found to be partially buried in the integument, and the surgeon should remove the projecting ends of the tubes as closely to the needle as may be practicable in order that they may not become occluded by doubling on themselves, when the dressing is applied over them. Various other plans, such as attaching to the distal ends of these tubes carbolized silk or catgut ligatures, splitting the tube and leaving behind a portion, are still employed by some surgeons. Catgut ligatures are sometimes used in lieu of the tubes or in addition to them, so that the former can be withdrawn and the catgut left *in situ*.

Sutures.—The metallic sutures should always be employed to close the deeper parts of an amputation wound, and none are better adapted to this purpose than those cut from the ordinary iron wire commonly used by florists in arranging their bouquets. I believe this wire to be fully equal and in many respects for this purpose even superior to the best silver wire. The catgut may be used in closing the superficial parts of these wounds, where there is no appreciable tension and where a suture is not required more than forty-eight to ninety-six hours. Even these possess no advantage over the iron wire. I have no longer any use for the carbolized silk sutures, inasmuch as I strongly prefer the wire and catgut.

Protective.—This article is employed for the purpose of protecting the wound against the irritating effects of the carbolic acid, and it also enables the surgeon to remove the dressing

without disturbing the relation of the flaps to each other, or causing the patient so much pain as would otherwise follow these manipulations. The protective should always be immersed in the 1–40 solution of carbolic acid before it is applied over the wound, and care should be taken not to occlude the openings in the drainage tubes with it. This may be readily avoided by making openings in the protective, which permit the passage of the ends of the tube, or, which is more frequently the case, the placing of the openings in it, exactly opposite to the openings in the tubes. The amount of protective required in dressing an amputation wound is comparatively small. It need not be more than one inch and a half in width and long enough to cover the entire line caused by the approximation of the flaps.

Mackintosh.—This name has been applied by the manufacturers of Manchester, England, to a thin cotton cloth which is rendered impervious to fluids by the application on one side of a layer of vulcanized rubber. It is an article extensively used in the manufacture of hats and caps, and is commonly designated as "sweat proof." The gutta-percha tissue is even preferable to the sweat proof because it is more pliable and equally impermeable. The Mackintosh is employed to prevent the direct passage of the wound secretions through the guaze, which would soon dissolve out all the carbolic acid stored up in the small portion which is thus moistened, and at this point permit the germs to penetrate to the wound. The gauze is commonly cut in squares for application over the stump after the amputation of a limb, and in all these cases the squares of Mackintosh are made about two inches smaller than those of the gauze, *i. e.*, if the gauze is sixteen inches, the Mackintosh should be about fourteen. Two squares, or layers, of Mackintosh are usually employed in each dressing, and these should be carefully examined to determine their impermeability, and if found satisfactory they are then placed in the 1–20 solution of carbolic acid for the requisite time prior to their applications, and when taken from this solution they should be freed from it by being well squeezed in the hand, care being taken not to rupture or tear it

while so doing, after which one layer of Mackintosh should be placed between the first and second, and the other between the second and third external layers of gauze, care being taken to preserve at every point about the limb the marginal border of gauze.

Antiseptic Gauze.—There are two kinds of antiseptic gauze imported, the carbolized and the thymolized, but both are made of a coarse meshed cotton cloth called "mull" in Great Britain; and known here as cheese or dairy cloth. The carbolized gauze is generally employed and is certainly preferable inasmuch as the carbolic acid is less irritating to the wound than thymol. The following directions for the preparation of this gauze are given by Dr. Wier: "This cloth is heated beyond 212°, then sprinkled with its own weight of a mixture of carbolic acid, 1 part, common resin, 5 parts, and paraffin, 7 parts, prepared by mixing together the two latter in a water-bath, and then adding the acid by stirring. The impregnated cloth is afterswards kept under pressure in a water bath box for an hour or two to disseminate equally the liquid, when the material is fit for use. The resin, it is well known, gives off the acid slowly—that is what is wished for—but it would leave the gauze too sticky were not the paraffin joined to it." . . . His own preparation, however, "is managed a little differently; for the heated cloth is immersed in the melted material by passing under rods near the bottom of the hot box containing the mixture, and, before emerging from this box passing between two confronting rubber strips (in fact, weather strips), which remove the surplus of the mixture; it is then caught on a roller, on which are passed at the same time, from another roller immediately below it, three to five layers of heated unprepared cloth. This tight roll of immersed and dry cloth has sufficient heat in it to cause the proper dissemination of the mixture through all the layers before it cools. Only occasionally is it found necessary to place the roll for further heating in a hot-air chamber. The impregnating layer is sometimes found a little too stiff, and is used in the manufacture of bandages. . . . Details of the preparation of this and other materials are dwelt upon because mistakes

are continually occurring; as confirmatory of this, it is necessary only to remark that a firm concerned in manufacturing the gauze in this city has failed, until recently, to appreciate the necessity of previously heating the cloth to insure the thorough penetration of the mixture into its substance, with the result of the central fibres being found imperfectly charged from neglect of this precaution."[1]

The most frequent causes of failure among those who are not expert in the use of the Lister antiseptic wound treatment, unquestionably arise from the bad quality of the material employed and a bungling application of the same. It should, therefore, be recognized as the first duty of the surgeon to determine the quality of each article employed in this dressing; and also to familiarize himself with every step in its application before he attempts to employ it.

Dr. Robert F. Weir, of New York, in the paper to which I have already alluded, has anticipated the wants of the surgeons who are about resorting to the application of Lister's antiseptic system of wound treatment, and such as desire it may obtain from his article more detailed information than is given in this work.

Application of Lister's Antiseptic Treatment.

The application of this treatment in cases of amputation wounds should commence by thoroughly cleansing the parts through which the incisions are to be made. The following order may be advantageously followed: first, thoroughly wash the parts with soap and water, after which it should be shaved to remove all hairs, and then bathed in sulphuric ether to remove all fatty matters, and afterwards thoroughly cleansed with 1–20 solution of carbolic acid. The cleansing of the parts is most conveniently effected by the use of a clean, stiff, nail-brush. The carbolic acid spray should now be directed on the limb at the point at which the operation is to be performed, and kept continuously playing on it during the whole operative pro-

[1] Ibid. p. 566.

cedure, even including the dressing of the wound; or should the operator prefer it, he may unquestionably substitute for this spray continuous irrigation with the 1–40 solution of carbolic acid with equally good results. I now cite Dr. Weir's excellent and explicit directions for the dressing of the wound. "Having made these preparations as follows, and the directions relative to the instruments, sponges, hands, and the adjacent skin, having been properly complied with and the surface of the body not too much exposed, the operation or incision is begun by directing the spray . . . upon or a little above the intended wound. The management of this is one of the most important duties to be intrusted to an assistant. Currents of air may turn away the cloud of spray, the position of the limb may be changed, the surgeon may unexpectedly place himself or hands in the way, and thus screen the wound, etc. All these difficulties must be looked after by the attentive lamp-holder. It is well to have an extra spraying apparatus accessible. . . . If the spray should suddenly cease, the wound should be at once covered with several layers of gauze wet with 1–40 solution, called sometimes the 'guard.' The incisions having been made, all the bleeding points must be secured by catgut ligatures, both ends of which are to be cut off short. . . . A drainage-tube or tubes should be placed in the deepest part of the wound, so as to drain off all accumulating fluids."[1] The wound should then be accurately closed with metallic sutures, and, since perfect approximation of the entire cut surfaces is what the surgeon aims at, it may therefore be necessary in some cases in order to accomplish the same, to introduce many sutures. "A small piece of protective, previously dipped in a weak solution of 1–40, but only sufficiently large to thoroughly cover it, is then to be placed over the line of junction of the edges of the wound, with openings cut in it for the drainage tubes. . . . Over the wound now covered with the protective is to be placed a large separate layer of gauze, which has been dipped in a weak solution of 1–40 of carbolic acid. This is used in order to nullify the putrefactive elements that may be deposited in the exposed

[1] Ibid. p. 569.

layers of the dry gauze; which latter is, after stopping the spray, then applied in a thickness of eight folds, largely overlapping the wound, and having a piece of Mackintosh with the rubber side down interposed between the seventh and eighth layers. If the discharge is likely to be great a larger number of layers can be used, or extra layers placed where fluids, would be most likely to gravitate. The Mackintosh should be about one inch smaller than the gauze, since it is intended to convey any discharge that may soak through it towards the edges of the dressing, where it can be dected by the surgeon or nurse while it is yet resting in the antiseptic material. All fluids are thus compelled to permeate the whole dressing and to be constantly in contact with the carbolic acid. The dressing now completed, requires only to be secured in place, which is best accomplished by bandanges of the same guaze material as they will not slip. The many-tailed bandage is to be preferred for stumps since its application will not be so apt to displace the protective. If the edges of the dressing do not fit snugly to the skin, or if they come where the natural motions of the body render nicety of application difficult, the too free entrance of air can be prevented by either stuffing in pieces of crumpled carbolized gauze or salicylic cotton along the edges, or by using a bandage of elastic webbing lightly applied so as not to give discomfort to the patient. The dressing is changed as a rule . . . in twenty-four hours, even though it is not stained at its edges; and sooner if the secretions are formed in a sufficient quantity to bring about this result. This often occurs by reason of the irritating nature of the carbolic acid, which increases to a considerable degree the secretions of the wound. If the protective is unchanged in color, the wound is certainly aseptic; if it is not, it will show dark-brownish spots, the result of the action of the liberated sulphur upon the lead in the oiled silk. These remarks about the protective hold good only of incised wounds. In contused wounds the changes of color are met with even though the wound is doing well. To expose the wound, the same precautions as to hands, instruments, etc., are to be taken as at the operation. The spray is directed on the dressing, and particu-

larly on its edges, and the encircling bandage having been cut or removed the folded gauze is carefully raised while the spray is turned into the angle between it and the skin. The parts adjacent to the wound are lightly wiped by a carbolized sponge or cloth, to remove the secretion, which is generally a bloody serum. If the evidence is favorable, washing out the wound is to be carefully abstained from, and the drainage-tube is not to be removed; nor is this to be done until the third or fourth day, unless some sign is recognized of its being choked up, as, for instance, by tension, etc.; whenever it is taken out it is cleaned in the stronger carbolic acid solution of 1–20, and replaced previously shortened, if need be, according to the granulation or closure of the wound. Lister keeps them in until the wound is nearly or quite healed, that is, so long as the discharge is more than the mere drainage opening will account for, cutting them off at each dressing, and finding them often at the last dressing loose on the gauze with their track healed. In a redressing everything is renewed except the Mackintosh, which can be washed off with the carbolic solution of 1–20, and used again. It is preferable, however, to have two pieces, so that the one removed from a soiled dressing can be cleaned prior to its being employed again, when it is, of course, to be dampened with the strong solution. The renewal of dressings after this one of examination, depends on the profusion of the discharge, the sensations of the patient, and the temperature elevation. The latter should, in a satisfactory case, be either normal throughout or but slight in amount, and subside within forty-eight hours or thereabout. If nothing wrong occurs, the dressing can be left on for weeks. . . . In one case, by sprinkling the under surface of the gauze with salicylic acid, it was kept on for six weeks without either odor or irritation. Generally it is retained from two days to a week."[1]

In conclusion, it is proper to call attention to the fact that pathologists have discovered that septic infection does not occur in wounds which are perfectly covered with healthy granulations;

[1] Ibid., p. 570.

and consequently many surgeons, in their practice of antiseptic surgery, have been accustomed to remove the Lister dressing after the lapse of about three weeks, if the wound still remained unhealed at that time. The only plea offered in behalf of this action, is the surgeon's desire to diminish the expenses of the wound dressings, but *I am satisfied by my own experience that it is not a safe procedure in many cases.*

GUÉRIN'S COTTON-WADDING DRESSING.

Guérin's treatment of wounds, like Lister's, is based on the theory that traumatic inflammation, septicæmia, pyæmia, erysipelas, osteo-myelitis, and all other septic conditions arising in connection with wounds take their origin, and are entirely dependant on the presence of germs which have been introduced into the wound secretion while it is still in contact with the living tissues of the wound. It was during the first siege of Paris, in 1870, that the distinguished surgeon, Alphonse Guérin while contemplating the enormous mortality among the wounded in the Parisian hospitals, and at almost every point on French territory where a considerable number of wounded had been collected; conceived the idea of employing cotton as a dressing for wounds and perfected the method which now bears his name. Prior to the introduction of this new mode of treatment nineteen cases out of twenty on whom an amputation of a limb was performed died from some septic complication. It was on the first day of December, 1870, that this surgeon tried his treatment at Saint Martin's Hospital on a soldier, who had received a gunshot wound of the left forearm, which had caused a comminuted fracture of the radius and an opening of the radio-carpal articulation. This wound necessitated the removal of several bone splinters, and an exsection of the lower portion of the radius. The new treatment was employed with complete success. The events of the Commune soon offered an excellent opportunity to put the cotton-wadding treatment to a severe practical test, and the results obtained were highly satisfactory. The forty-one capital operations rendered necessary by severe traumatisms, produced

by firearms, gave twenty-four recoveries and seventeen deaths. The success of this treatment becomes much more striking when compared with the old methods employed during the same period at other hospitals in Paris.

At Saint Antoine there were nineteen amputations and sixteen deaths, three exsections and three deaths, and in twenty-five attempts to save limbs without operative interference there were twenty deaths. At the Rothschild's Hospital there were four amputations and four deaths. At the Lariboirière there were thirty-five amputations and thirty-three deaths, whilst at the Grand Hotel (service of Nėlaton), there were seventy operations and sixty-eight deaths. The success of this treatment made a decided impression on the minds of Parisian surgeons. Several, among others, MM. H. Larrey, Gosselin, Broca, and Verneuil met at the St. Louis for the purpose of investigating these results for themselves. The majority of them afterward made a trial of this treatment on their patients and were satisfied with it.

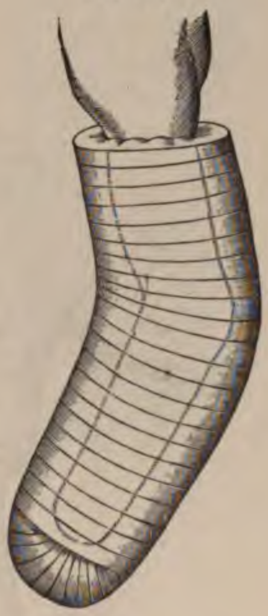
From Paris this mode of treatment was not slow to spread to other countries. Especially the English, Swiss, and Belgian surgeons adopted this new mode of wound-treatment about the same time, and many of them ranked it with the very best wound dressings. Its chief advantages are attributable to the fact that the cotton acts as a filter and thus prevents all germs from entering the wound after its application, that it assists by its equitable and elastic pressure in maintaining the flaps in contact with the wounded surfaces, and furthermore that the changes of these dressings are infrequent and do not disturb the relations of the parts. The marked success obtained by M. Alphonse Guėrin by this mode was unquestionably in a considerable degree dependent on the remarkable precautions which he took to prevent contamination of the wounds. The cotton-wadding and bandages were selected with the greatest care, both were required to be new and perfectly clean, and were never kept in a hospital ward or where they might become accidentally contaminated. The wadding employed for this purpose is that most generally used in surgery, and consists of sheets of carded

cotton which have not been gummed. The same precautions were taken against the contamination of the wound. The patient was not permitted to enter a hospital ward before the application of the dressing; but was always taken to the amphitheatre for this purpose, and even here scrupulous care was exercised in order to avoid the entrance of germs into the wounds. The surgeon's hands and instruments were thoroughly cleansed before use, and never unnecessarily introduced into the wound, although care was taken to remove all foreign substances from it prior to the application of the dressing. The application of this dressing was then carefully and artistically made in accordance with certain scientific principles.

The amputation having been performed, the bleeding vessels are tied with carbolized catgut ligatures, and its ends are cut close to the knots; the wound is washed with carbolized hot water to arrest all further oozing of blood, and afterwards carefully bathed, together with the entire surface of the injured limb, with the 1–20 solution of carbolic acid, or the camphorated solution of alcohol. The parts are then dried with disinfected compresses, and those which are hot are considered preferable. An assistant now seizes the flaps with both hands, separating, and at the same time drawing them forward in such a manner that the intervening space resembles a ball. The surgeon then proceeds to carefully carpet the wound with some pledgets of cotton which are placed in position by the aid of the dressing forceps; and to this layer, successive layers are added until the entire cul-de-sac between the flaps has been filled. He envelops, afterwards, the whole length of the limb, which is kept in the extended position together with the stump in a thick layer of cotton, forming over the peripheral extremity a firm cushion by the approximation of these layers, or by arranging new layers in recurrrent lines as in the formation of the capelina. Instead of applying singly layer after layer of cotton wadding, which requires much time, it is more simple and expeditious to envelop the limb in leaves of the wadding which have been placed one upon another; thus arranging a sufficient quantity of cotton for the whole bandage; and even when applied, to

project beyond the end of the stump, while at the side it ought to be from 9 to 11 inches in thickness. The assistant now steadies the limb, and the surgeon commences the application of the roller bandage. The first turns are made loosely about the limb, and it is then carried over the stump in long recurrent layers, which are afterwards fastened by other turns of the roller bandage around the limb. The surgeon thus continues alternating the recurrent with the circular layers, tightening gradually this bandage until he employs his whole muscular strength in the application of the final layers. This bandage may be considered well applied, when it fits evenly and accurately the subjacent parts, while its general form is regular, the end covering the stump blunt, in the form of a capelina, its central portion being raised in the form of a cone, giving proof that the wadding has been evenly and well packed, that the cotton is here of the same thickness as in other portions of this dressing, and not thinned or improperly compressed by any of the turns of the roller bandage. M. Alphonse Guérin is accustomed, after the application of this dressing in cases of amputations of the limbs, to strike it with his fist, or box it, as he picturesquely designates it, in the presence of his English assistants, without giving his patient any pain or even a disagreeable sensation.

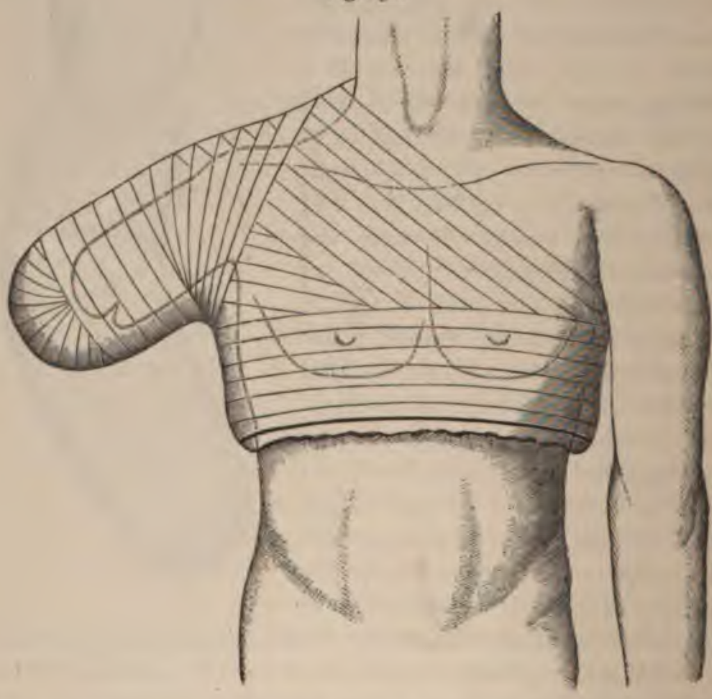
Fig. 135.



The method of procedure which has already been described should be so modified as to adapt it to the different methods of amputating. Those surgeons who are opposed to all attempts to obtain union by first intention in cases of flap amputation,

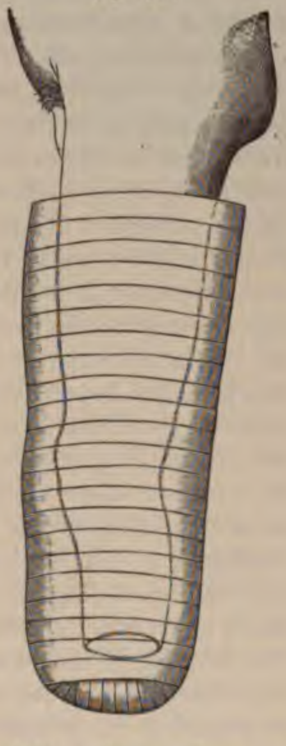
carpet the entire surface of the wound, as soon as the bleeding has been controlled, more or less thickly with cotton wadding, and then fill up the intervening space between the flaps. A similar method is frequently employed in cases of the circular amputation. M. Verneuil places a portion of carbolized gauze between the flaps, while other surgeons employ gauze which has been saturated with carbolized oil. A still more advantageous method of procedure consists in the strict observance of

Fig. 136.



the antiseptic precautions, the use of the carbolized catgut in the ligation of all bleeding vessels, the proper introduction of drainage tubes over the stump, the closure of the wound with metallic sutures, the application of two layers of the carbolized gauze, which should be previously moistened in the 1–20 solution of carbolic acid, after which the cotton wadding should be applied

Fig. 137.



in the usual manner. In amputations of the hand and forearm, the bandage extends upward to the axilla as shown in Fig. 135.

In amputation of the arm, the dressing extends upward to the neck and incloses the chest. This dressing is shown in Fig. 136. The illustration exhibiting the appearance of the stump after the applications of the dressing in cases of amputations of the thigh, may be seen by reference to Fig. 8, Chapter IV. The appearance of this dressing is well shown in cases of amputation of the leg in Fig. 137.

The above illustrations represent the appearance of the stumps in only a limited number of amputations, but they are deemed sufficient to convey a correct idea of the principles on which the practice is based, and furthermore to enable the surgeon to apply the dressing intelligently in all cases where its use may be advantageous.

O'Halloran's Open Method.

During the early part of the eighteenth century, the flaps having been brought in contact with the other cut surfaces, the whole stump was enveloped in a load of dry lint immediately after the performance of any amputation; but in the year 1765, Sylvester O'Halloran, an eminent surgeon in Limerick, Ireland, having observed the unsatisfactory results of this method of after-treatment, dressed the flaps and other cut surfaces as separate sores until about the twelfth day; but when the inflammation had passed away and suppuration had become

thoroughly established, he recommended that the bare flap be turned up against the naked stump and secured there by means of plaster, compresses, and bandages. This recommendation was adopted by Mr. Lucas, of Leeds, in 1779, who had already put this method in practice on two patients with satisfactory results, and was convinced that it possessed many advantages over the operative procedures commonly employed at that time for the removal of diseased or injured limbs. However, O'Halloran's method made little progress, as Alanson soon after demonstrated that the flaps might be safely closed immediately after an amputation, and by the observance of cleanliness and the avoidance of the absorption of the wound secretions, better results might be obtained, than the Irish surgeon had ever anticipated. O'Halloran's practice, which had been long neglected and almost forgotten, has been revived, and is again occasionally practised since the commencement of the agitation of the antiseptic treatment of wounds. The method, as recently employed, consists in placing a ball of oakum between the flaps, and then enveloping the end of the stump in the same material, which is generally extended up the limb from four to six inches. The dressing is then completed by the firm application of a roller bandage over the oakum and around the stump, extending it upward as far as may be necessary to prevent its slipping. This treatment belongs to a past age, and should be speedily consigned to oblivion, since it possesses no merit worthy of recognition in the present advanced state of surgery.

The Open Method.

This treatment consists in leaving the amputation-wound entirely open and freely exposed to the air, until its cut surfaces are completely covered with healthy granulations. The danger of septic infection having then passed, the wound is closed, and the union, which has already been delayed ten or twelve days, now goes on rather slowly. The object sought in this treatment is the avoidance of septic infection, and the surgeon expects to accomplish this object more or less completely by

exposing the wound to the air, and placing the stump in such a position that all its secretion may be promptly removed from its surface by its own gravity. The formation of a pellicle effectually shuts out atmospheric germs, and the position in which the stump is placed obviates thereby the danger arising from the decomposition of animal fluids while in contact with a fresh wound. The principal failures attending this mode of after-treatment are probably due to the entrance of germs into the wound prior to the formation of this pellicle, or the subsequent fissuring or removal of the same, which may permit the contamination of the wound at a later date. It is also possible, that owing to a faulty position of the stump, the flaps, or even the contact of some foreign substance with the wound, that the wound-fluids may undergo decomposition on the fresh wound before the formation of the pellicle. It, therefore, follows that this treatment should be so managed as to avoid, as far as possible, these dangers, and no modification should be introduced which can only serve to defeat the object sought to be accomplished. The following modification of the open treatment is said to have yielded good results at Bellevue Hospital during the last few years in cases of amputation-wounds. The house-surgeon, Dr. Frederick S. Dennis, describes this treatment as follows: "After a limb has been amputated the flaps are not even approximated, but left entirely open. A pillow of oakum is placed under the stump, which is allowed to rest upon this support until the wound is nearly healed. A small piece of gauze is placed over the contour of the stump, and a cradle is placed over the limb, so that the clothes may not come in contact with the painful extremity."[1] This is all the dressing that is employed, no sutures are used except in the lateral skin-flap method, as will be described. No adhesive plaster is employed, no oil-silk is placed over the stump, no bandage is applied, no dry charpie is stuffed into the wound, no fenestrated compresses are placed between the flaps; in other words, the stump is left entirely alone, just as the surgeon made it in his amputation.

[1] New York Med. Journ., vol. xxiii. p. 10.

The wound is thus allowed to drain freely, and the stump is gently washed at frequent intervals by means of an Esmarch's wound-douche. The water in this irrigator is impregnated with crystals of carbolic acid, and after this ablution, balsam of Peru (which makes a fine stimulating application) is poured over the granulating surface. The discharge which falls from the wound is removed every few hours in order to secure perfect cleanliness; and it is a fact worthy of observation that this discharge will not decompose when exposed to the cold air, but that it requires a warm temperature, such as exists in the stump itself, in order to develop putrefaction. The pus thus coming away from what would otherwise be a nidus of putrefaction, falls upon a piece of sheet-lint where the temperature is cooler, and thus does no harm. The stump is then washed at frequent intervals until suppuration has nearly subsided in the wound, and then the flaps are gradually approximated by means of strips of adhesive plaster. Too much importance cannot be attached to this method of operating by the lateral skin-flaps. It affords the best facility for free drainage, and makes the most serviceable stump. It is important to dissect the flaps very long when they are subjected to the open treatment, as shrinkage often follows exposure to atmospheric influences. This lateral flap method of amputating Dr. Wood has employed for many years in private practice with uniform success.

Callender's Modified Antiseptic Treatment.

This treatment aims to secure speedy healing of wounds by the following means, viz., the removal of all foreign bodies, including blood, coagula, and bone detritus, perfect coaptation of the flaps, efficient and thorough drainage, complete rest of the parts together with absolute cleanliness of the wound and the adjacent integument, thus preventing the decomposition of the wound-fluids and its resulting septic infection. He employs for the accomplishment of these ends the drainage-tubes for twenty-four to thirty-six hours, thus permitting the free escape of the bloody serum, and then bandages the stump to a well-padded

splint in order to prevent all voluntary movements and the disturbances arising from the involuntary twitchings of the muscles. He applies to the end of the stump a piece of lint which has been prepared by soaking in carbolized oil and requires that it shall be changed as often as may be necessary in order to keep the parts properly moistened. He uses in addition to the above-mentioned means, for the purpose of cleansing the wound and the adjacent parts as frequently as may be necessary, a glass brush dipped in a strong spirituous solution of carbolic acid. The mutilated limb is carefully suspended in a suspensory apparatus, in order that the necessary movements of the body may not be productive of suffering to the patient. The avoidance of pain, either physical or mental, was regarded by this distinguished surgeon as exerting a very important influence on the well-being of his patients after the performance of an operation, and consequently he directed much attention to its relief.

Markoe's Through Drainage in the Treatment of Wounds.

This treatment is generally regarded as a modification of the antiseptic method, although the author thinks that the carbolic acid exerts its chief beneficial effects by modifying the *vital action* of the parts to which it is applied, and thus controlling inflammation. He says on this subject: "The idea underlying the whole series of experiments, for such I am willing to consider them, is that by controlling the tendency to inflammation by the use of carbolic acid, applied constantly and in an effective way to the injured surfaces, we can obviate the dangers to which, in the process of repair, these wounds are liable, and that the success of the treatment will be in direct proportion to the degree of control which, by that method, we are able to secure."[1] The essential details of this method as applied to the treatment of amputation-wounds when given in Prof. Markoe's own language are as follows: "The operation was performed in the

[1] Am. Journ. of Med. Sci., vol. lxxix. p. 319.

usual manner, low down in the leg, with lateral skin flaps, . . and the wound was dressed with a single drainage tube. . . . This tube had been prepared so that the part within the wound had been perforated with a number of holes, care being taken that all that part of the tube which projected from the wound should be free from openings. The wound was then covered with the ordinary prepared carbolized gauze laid on in three or four thicknesses, first being well wetted with a 1–40 solution of carbolic acid, and so arranged upon the surface of the wound that the ends of the drainage-tube were free as they projected on either side. This we generally accomplished by cutting holes in the dressing opposite the points of entrance and exit of the drainage tubes, though sometimes the tubes could be brought out between the folded pieces of which the dressing was composed. This retained in position by a few turns of the thin gauze bandage also wetted with carbolic acid solution completed the dressing. The limb was then suspended from a framework so that it was raised about six inches from the bed, and swung easily from side to side on every motion of the patient's body. This arrangement was found extremely comfortable, and permitted the drainage from the wound to be freely discharged from the lower opening. Four times a day a solution of 1–40 carbolic acid was thrown through the drainage-tube with an ordinary syringe, and continued till the fluid discharged at the lower opening was perfectly clear. The result of this manipulation was that the fluid forced by the syringe into the upper end of the tube found its way freely into the cavity of the wound, distending it, and then found its way out at the lower orifice, carrying with it all the fluid secretions which otherwise would have been more or less confined within the wound. This distension of the wound by the injected fluid would not of course happen to any great extent if the whole tube including its lower orifice were free from obstruction, but it very often happened that the outlet was impeded by plugs of dried pus or by clots, and then the penetration of the fluid to all the recesses of the wound was very complete, a penetration which we considered so desirable that sometimes the lower ori-

fice of the tube was pinched by the finger and thumb, while the injection was being made for the express purpose of securing it."[1] This treatment with through drainage and the carbolic acid solution seems to have been continued from nine to twelve days, after which the tube was removed and the wound dressed with balsam of Peru.

Gamgee's Dry and Infrequent Dressings.

It must generally be admitted, as the author stated in his preliminary lecture, that; "Once parts have been brought together after division, they cannot be too studiously kept at rest, to which infrequent dressing is eminently conducive; yet you will see surgeons, in this and other schools, who dress an amputation daily from the first, and sometimes twice and even three times in the twenty-four hours. Pressure, gentle, uniform, sustained, I have taught you to look upon as an auxiliary of the very first importance in promoting healing action."[2] The same idea is forcibly expressed by the same author in another portion of his clinical lectures, where he writes as follows: "Once a recent wound has been nicely adjusted, the less it is interfered with the greater the chances of healing. Under such circumstances, to meddle without good reason is to muddle. In carrying out the practice of infrequent dressing, the thermometer is of the greatest use."[3] The above quotations put forth the essential principles on which this method of wound treatment rests; and, it now remains to detail the various steps in the application of the dressing. We find this description given in the author's own language in the case of an amputation performed just below the elbow-joint when he says: "I amputated just below that joint, utilizing some of the least damaged skin to cover the stump, which showed bruising of the muscles and effusion of blood into their substance. Two arteries were tied with silk, and some smaller ones twisted. Where the skin

[1] Ibid. p. 324.
[2] Clinical Lectures on Treatment of Wounds, London, 1878, p. 2.
[3] Ibid. p. 9.

was quite sound, the edges were brought together with two points of sutures; elsewhere the parts were approximated with strips of lint soaked in styptic colloid, a drainage-tube being left in the lower part of the wound, and the ends of the ligature brought out at the angle with the tube. The stump was covered with a layer of cotton-wool, and oakum over it. Rectangular pasteboard splints, extending from the end of the stump to the shoulder-joint, were applied with gently compressing bandages to insure perfect immobility and prevent swelling. When the apparatus was opened four days afterwards there was very slight sloughing of the margin of one flap; but the stump was of good color and healthy temperature, without tension. I removed the drainage-tube, brought the edges closely together by adhesive strapping, and reapplied cotton-wool and oakum as dry dressing, with pressure. The lad was discharged on the 17th of June, a month within a day from his admission, the stump, then quite healed, having been dressed altogether seven times after the amputation."[1] The modifications required to adapt this dressing to amputation wounds of the thigh, and other parts of the body, are slight, and consequently require no additional description. It should, however, be thoroughly understood that its proper application demands much skill and practice. The author says on this subject: "Of all surgical agencies none so beneficent as compression, none requiring more delicate manipulation. . . . To apply a nicely compressing bandage well, you must practise hundreds and hundreds of times."[2]

Hewson's Earth Treatment of Amputation Wounds.

The author of this treatment thinks the beneficial action of this remedial agent may be attributed to its chemical and physical properties and that the clayey earth possesses the power to generate ozone and deoxidate that which favors fermentative action. He also adds: "Nor should we in our estimate of the dry clayey earth's power in the healing processes overlook its

[1] Ibid. p. 21. [2] Ibid. p. 14.

influence on ammonia and other nitrogen compounds, which we have seen are not only the products of the normal changes, but are in themselves prone to induce disintegration wherever they are, and this independent of any extraneous supply of free oxygen. The presence of such products we have seen must be alike unfavorable in decay, putrefaction, inflammation, suppuration, and in any form of the healing processes; and the peculiar power, as demonstrated by Prof. Way's researches, in all the double silicates of alumina (which are the essential constituents of clayey earths), to absorb and fix such products, is one entirely independent of their power as deoxidizers or absorbers of oxygen, and gives them a property especially in the healing processes of fully as great value as either of those."[1] In further explanation of its chemical action he adds: "The double silicate of alumina and potash, which we know is abundant in the clayey earths which I have been using, must therefore have its potash displaced by the free ammonia generated in all retrograde metamorphosis. Hence when such earth is put in contact with a wound or granulating surface, the ammonia from the effete nitrogenized tissue, pus or exudation, will be absorbed, and the potash base of the silicate will be set free. The presence of the potassa so liberated must, according to the views of Schmidt, Lehmann, and others, increase or tend to make more perfect the formative action in the part. Hence we may claim for earths possessing such silicates a positive power to aid formative action in the flesh when brought in close contact with it."[2] It is also claimed by the author of the dry earth dressing that it not only aids the formative action, but is an effective deodorizer, allays the pain in the parts to which it is applied, and lessens the suppuration in wounds. The particular kind of earth employed in this treatment is certainly a matter of some importance to the profession, and I shall therefore give it in Dr. Hewson's own language, who says: "That, unless it is otherwise specified, 'earth,' 'clay,' or 'clayey earth,' spoken of in this volume, was

[1] The Use of Earth in Surgery, by Addinell Hewson, M.D., Phila. 1872, p. 308.
[2] Ibid. p. 309.

always essentially the same, namely, from deep diggings, well dried (but not roasted), and sifted through a fine flour-sieve, the yellow subsoil common everywhere in our city and vicinity, rich in ferruginous clay, and entirely free of all sand, grit, or foreign matter."[1] The remedial agent, its *modus operandi*, and the virtues claimed for it being known to the surgeon, we are consequently enabled to proceed immediately with a description of its application, which may be briefly given as follows: The amputation having been performed, the vessels ligated, or the bleeding from them otherwise permanently controlled, drainage-tubes introduced, the flaps brought together in such a manner as to approximate the entire cut surfaces, and retained in this position by means of sutures or such other measures as may be preferred by the operator, the whole stump should then be covered with dry garden earth and retained by the Scultetus of dry papers, a suitable splint and muslin bandage. This dressing ought to be removed so often as it becomes moistened with the wound secretions, even in the slightest degree on its extreme surface, the earth being scraped off with a dull knife, and the stump further cleansed with warm water, after which the earth is again applied. The removal of the drainage-tubes, sutures, and various other details connected with the management of stumps after amputations, should be governed by the same general rules applicable in the other forms of after-treatment.

Water Dressings.

When the attention of the profession was first called to this agent as an application to recent amputation-wounds, it was unquestionably entitled to be regarded as a decided improvement over the existing practice of stuffing wounds with dry lint, or the application of the foul cerates; but in the light of modern science, it must be looked on merely as a measure for applying heat, cold, and moisture to the external surface of the stump. It may, therefore, be safely asserted that its chief value is nega-

[1] Ibid. p. 19.

tive, and consequently the surgeons who employed it did not materially injure the prospects of their patients. Its use in these cases was generally empirical, or at least controlled more frequently by the fancy of the surgeon than by any sound surgical principle, and hence one surgeon employed only cold water, while another adhered to the use of the hot, and the third preferred the tepid. The progress of science having displaced this method of treatment, it is unnecessary to enter more fully into the details of its application.

The Management of the Patient during the After-Treatment.

The well-being of our patients after the performance of an important amputation, or any other capital operation, depends so much on the subsequent management, which is essentially the same with all the different forms of wound-dressing, that a description of its more important details should not be omitted from any systematic treatise on this subject. Under this caption we ought to include all those attentions required for the general health, comfort, and speedy recovery of our patient. It is equally as important to secure good hygienic surroundings for the patients as that proper attention should be given to the management of the stump. The latter may often require to be elevated and protected by a cradle to secure the greatest amount of comfort attainable under the circumstances, but it is equally important that fresh pure air should fill the sick chamber in order that the various functions of the body may be properly performed. The result of an amputation unquestionably depends more upon the attention given to these minor details than upon the operative procedure itself. There is much difficulty in giving fixed rules for the management of these cases, and, therefore, the surgeon is compelled to meet the indications as they arise. It is, however, thought that some general hints on this subject may be found serviceable, and we will, therefore, mention a few in their usual order of occurrence. The limb having been amputated, the dressing of the stump should generally be

completed with the firm application of a roller bandage, which in every case should extend to or above the proximal joint, *i. e.*, in amputation of the forearm it should be commenced as near the border of the stump as possible, and extended above the elbow, and in amputation of the arm it should be carried up to the axilla. The object sought to be accomplished by this bandaging is the arrest of the muscular twitching in the stump, and it is unquestionably serviceable. The next subject demanding the attention of the surgeon is the position in which the stump should be placed, and how supported. There are commonly only two factors bearing on these questions, the one being the comfort of the patient, and the other the drainage of the wound; although the dressing employed may necessarily exert some influence on both position and support. Experience shows that our patients are most comfortable when the stump is moderately elevated upon a hair pillow, or properly suspended in a sling. In the former case the lateral movements of the stump are controlled by means of sand bags properly placed, and the cleanliness of the bedding is preserved by proper use of rubber cloth, oiled silk, muslin, etc. The stump should also be protected from the weight of the bed covers by the use of a surgical cradle. The further management of the case must depend on the existing indications, but especial care should be taken to keep the patient free from pain, and to secure, if possible, sufficient sleep. The accomplishment of this object commonly requires the use of morphine or some other anodyne. Should a patient fail to rally promptly after the performance of an amputation the chief remedial agents indicated are artificial heat and stimulation. Reaction being fully established at the expiration of the first twenty-four hours, the patient should then receive a cathartic, unless contra-indicated by previous treatment, or the existing condition of the bowels. It will always be found that unloading the alimentary canal in nearly all these cases not only improves the patient's digestion, but also his general condition. Only liquid food should be supplied to these patients for several hours after the performance of the operation, but the quantity and duration of this sort of alimentation can only be regulated by the

attending surgeon. Tonic medicines may become necessary during the convalescence of the patient; but, here again, the medical attendant must exercise his own judgment. The general management of these cases may be finally summed up as follows: a strict observance of all the recognized hygienic laws, constant vigilance on the part of the surgeon and other attendants, in order that the patient be made as comfortable as possible; and, furthermore, a strict adherence to the principles and practice governing that method of wound dressing which has been adopted in each particular case.

CHAPTER VIII.

STUMPS, CLASSIFICATION, RELATION OF CAUSE TO EFFECT. PRODUCTION OF DESIRABLE RESULTS. THE SELECTION AND APPLICATION OF ARTIFICIAL LIMBS AFTER AMPUTATIONS AND DISARTICULATIONS. GENERAL HISTORY. INCOMPLETE AMPUTATION OF THE HAND. DISARTICULATION AT THE WRIST, AND AMPUTATION OF THE FOREARM. DISARTICULATION AT THE ELBOW, AND AMPUTATION OF THE ARM. DISARTICULATION AT THE SHOULDER. MEASUREMENTS REQUIRED FOR THE MANUFACTURE OF ARTIFICIAL ARMS. PROSTHESIS OF THE LOWER EXTREMITIES. PARTIAL AMPUTATIONS OF THE FOOT. TIBIO-TARSAL AMPUTATION. AMPUTATION OF THE LEG. APPARATUS FOR THE AMPUTATION OF THE LOWER THIRD OF THE LEG. AMPUTATION OF LEG ABOVE THE LOWER THIRD. DISARTICULATION AT THE KNEE. AMPUTATION OF THE THIGH. COXO-FEMORAL DISARTICULATION. CRUTCHES. MEASUREMENTS REQUIRED FOR THE CONSTRUCTION OF ARTIFICIAL LIMBS FOR THE LOWER EXTREMITIES, ETC.

THE portion of a limb which remains after the performance of an amputation is generally designated as a stump, and stumps may be conveniently classified as good, bad, or indifferent; but the practical question which arises in this connection is, How do these varieties differ? It is certainly necessary that surgeons should be in accord on these points, that they may endeavor during the whole management of a case to secure the most desirable results. It will be universally admitted that the best stumps are those which are the most serviceable and least troublesome; and consequently a practical test of their value will be found in the ability of the maimed to wear without pain or inconvenience to himself an artificial limb, which possesses the highest possible degree of utility. The conical stump, which is shown in Fig. 138, has long been regarded as the opprobrium of surgery. These stumps vary greatly in the degree of their

conicity and other pathological peculiarities. In the following figure it will be observed that the conicity is very marked, and that there is also a protrusion of the bone. This marked protrusion of the bone is commonly very limited in its duration, and is soon followed by exfoliation, after which the remaining portion is thinly covered with cicatricial tissue. In many of these cases the cicatricial tissue not only covers the end of the bone but forms a border around it of varying width, and since this substance possesses little vitality it merely requires a slight injury to produce an open ulcer. Furthermore cicatricial tissue continues to contract several months after its formation, and in this manner renders more tense the already existing tension on the integument and other adjacent tissues. It may, therefore, be safely asserted that while the other factors of a conical stump remain the same, the greater the amount of cicatricial tissue found in its coverings, the greater will be the danger of ulceration; since it is unable to bear the slightest pressure or motion. The pressure of the cicatrix upon the nerves of the stump may also give rise to neuralgia, and, in fact it is probable that this painful affection is generally caused by pressure or irritation; although in some rare instances it may arise from constitutional causes. This painful condition without regard to its cause is commonly associated with a bulbous enlargement of the ends of the nerves, which generally demands for its relief the reamputation of the limb, or the removal of a portion of the bone with its adhering cicatrix. The firm adhesion of the cicatrix to the bone is another unfortunate complication of stumps, and the evils arising from it are generally proportionate to the extent of the surface which is thus covered. There are other important changes in the soft parts which are closely allied to the metamorphosis in

Fig. 138.

the bone of the stump, and these will be mentioned hereafter. Some of these changes are only observed in those cases where the amputation had been performed on a young subject in whom the bony skeleton was not yet fully developed, while others belong to all healthy stumps. The changes in the osseous structures of the conical stumps are often dependent on the same causes as the morbid conditions in the soft parts, and consequently the subject of causation may be discussed under the same head.

An inflammatory complication of an amputation is unquestionably the most frequent cause of this detestable stump in these times, although it was formerly most frequently attributed to an original deficiency in the length of the flaps, the retraction of the same by muscular contractions, or to the sloughing resulting from the lesion which necessitated the operation. The bungling manner in which amputations were universally performed in the earlier times, undoubtedly had much to do in the production of the conical stumps; but even in those days septic infection and its accompanying inflammations were potent agents. It was not until Prof. Lister had perfected his antiseptic system of wound-treatment, that surgeons were fully able to comprehend the baneful influences arising from septic infection, which has since been proven to be the initial condition of all local inflammations arising in connection with traumatisms. A strict adherence to this system of practice in the management of amputation wounds, enables the surgeon to avoid such troublesome complications as osteo-myelitis, erysipelas, burrowing abscesses, septicæmia, pyæmia, etc., in all those cases where the infection has not taken place prior to the performance of the amputation, and is also equally efficacious in the avoidance of conical stumps.

Prof. Billroth has called attention to another morbid condition of the stump which he designates as conical, although the pathological conditions differ widely from that which has already been described under this name. He says: "The majority of stumps become conical in the course of years, even though they are covered with skin; this occurs most certainly

in weakly and atrophied individuals, and especial in those in whom amputation has been performed for caries of joints, and who subsequently become affected with caries in other bones or in the stump itself, or with pulmonary tuberculosis or lardaceous disease. The bones of such stumps become atrophied and their cortical layer thin. Short stumps of the thigh form almost the only exception to this. If these are much used for walking, the muscles which pass from the pelvis to the thigh become strongly developed, the skin also participates in this good nutrition, and the stumps become stronger than they were immediately after the operation."[1]

These inflammatory complications may produce the conical stump by expending their force either directly on the bone or the soft parts; but it is more frequently accomplished by involving both these factors; thus it will be observed that osteo-myelitis always implicates the soft parts as well as the bone before the exfoliation occurs, and its order of occurrence is as follows: septic infection, septic inflammation, and necrosis. This necrosis may be limited to a very small portion of the end of the bone, or it may involve the entire shaft. In some cases the sequestrum or exfoliation is a mere spicula of bone from some portion of the circumference of the distal end of the bony stump, and in others it is a complete ring of the same. These exfoliations are always more or less irregular, and the same may be said of the distal end of the bone of the stump from which they have been removed. It is therefore evident that the bone of the stump may be simply pointed, and at the same time very irregular, or of almost any conceivable shape. This condition is more marked immediately after exfoliation, and will be gradually improved during the first year. It is now necessary to investigate in this connection the results of amputations performed on young persons in whom the osseous system is only imperfectly developed. The consideration of this question involves the study of the normal development of the bone, and likewise the influences which bear on its growth after the per-

[1] Surgery, vol. ii, p. 518, New Sydenham Society, 1878.

formance of an amputation in a young subject. The regularity of the development of the bones is in harmony with that of the muscles and the various organs of the body. This development, which is in accordance with the general law, gives to the femur of the right extremity the same size and shape as the left, while the muscular growth in all parts of the body keeps pace with the osseous. It is admitted by physiologists that, "in the long bones, an increase of thickness is caused by the continual growth and ossification of the blastematous substance beneath the periosteum, and an increase of the length is caused by the growth and ossification of the layers of cartilage between the epiphyses and the shaft."[1]

This has been demonstrated by the experiments of Hales, Du Hamel, Hunter, Stanley, Flourens, Humphrey, and Gueterbock. It has also been shown by Humphrey "that the extension of the shaft takes place most quickly, and is most prolonged, at the end where the bone can best bear the weakening consequent on the more rapid changes in the growing matrix; and that is usually the larger end. For instance, the lower end of the femur is larger, and is more favorably circumstanced for bearing weight and resisting muscular force than the upper end; and the ossifying processes are much more active, and are longer continued at the lower end than at the upper. In the tibia, the lower end is at a disadvantage in comparison with the upper, in consequence of its smaller size, the greater weight borne by it, and the violent shocks to which it is exposed from its closer proximity to the ground, and there is less growth here than at the upper end. In the upper limb the conditions are in many respects reversed, and growth is, consequently, more active at the upper part of the arm and at the lower part of the forearm."[2] Furthermore, "it would seem that the growth of the soft parts is regulated by, and dependent on, the growth of the bones; and that the height of a man is mainly determined by the change that takes place in the shallow strata of cartilage connecting the epiphyses and shafts of his several bones. Pos-

[1] Medico-Chirurgical Trans., vol. xliv. p. 117. [2] Ibid. p. 118.

sibly this influence of the bones is attributable to the tension which this elongation exerts upon the soft parts. The tension so caused, operating upon all the structures along the limb, may excite and regulate their growth, just as we observe that the slight stretching of the cellular tissue of the skin and some other tissues, consequent on a tumor forming slowly beneath them gives rise to an increase in their growth. We must not, however, overlook the evidences of reciprocal influence of the soft parts, and particularly of the muscles, upon the growth of the bones. This is shown by the relation which the thickness and density of a bone almost invariably bear to the strength and activity of the surrounding muscles; and when the muscles of a limb are inactive in childhood, from paralysis or disease of a joint, the growth of the bones upon which these muscles act, or, it may be, of all the bones throughout the limb, is usually impaired."[1]

It may now be safely asserted, that if the facts are as they have been stated in the above; that the growth of the bone in the stumps of persons who have undergone amputation in childhood, cannot be proportionately as rapid as it is in the opposite unmaimed extremity; since the bone of the stump has been deprived of its epiphyseal line of cartilage at one end, and also deprived in a measure of that stimulus to growth which is supplied by the natural use of the parts. Both experimental inquiry and observation confirm the above conclusion with very few exceptions. It has been supposed in some cases that a failure in the growth of the soft parts to keep pace with the development of the bones had occasioned conical stumps, but additional proof is required to establish this point. The knowledge which we possess of the growth of bone, including the factors involved in it, justifies the conclusion that the preservation of a periosteal flap for the purpose of covering the sawn end of the bone of the stump cannot add to the longitudinal growth of the bony stump, even though the operation were performed in childhood; but the preservation of the epiphyses

[1] Ibid. p. 125.

will contribute more or less to this result. Having mentioned those factors which are generally considered in connection with a conical stump, and the causes of the same, it now remains to call attention to certain other abnormal conditions which are only occasionally seen in the bony stump. An exostosis may appear on the sawn surface of the stump, and it is generally caused by pressure or irritation in the wearing of an artificial limb; and should it give rise to serious trouble, its removal may be easily accomplished by excision. A deformity which is rarely seen in the human species; but which is more common in the lower animals, consists of a crookedness, bowing or twisting of the bony stump, and is supposed to be caused by the restraining action of the cicatrix, and an inequality of growth between the bones and muscles. Atrophy is another very rare deformity of the bony stump, although exceedingly common in the muscles, and it probably arises here from the same causes which give rise to it under other circumstances, and is commonly limited to the distal portion of the stump. Having already given our attention to a number of ill conditioned stumps, which are justly regarded as the opprobria of surgery, we will now turn to the consideration of the well-favored and serviceable memento of skilful surgical practice. This stump is traversed by a single narrow line of cicatricial tissue, thus showing that the flaps united by first intention, and the mobility of the soft parts over the end of the bony stump ought to be so free as to convince the surgeon that there is very little, or no adhesion between them and the bone. This model stump prior to the application of an artificial limb ought to present the exact semblance of the end of a perfect ovoid, and consequently without wrinkle or furrow. The soft parts covering the bone at this time are integument, adipose tissue, and muscle, but after an artificial limb has been worn a brief period, it will be found that the muscular and adipose tissues have completely disappeared as a stump covering, and the integument will now present a more or less wrinkled and furrowed appearance; but it should still remain more or less loose and movable. It should, however, be remembered that while these important changes are taking place,

others of equal importance are going on around the sawn end of the bony stump, which in a measure preserve that contour which has already been described. It is unnecessary here to enter minutely into the generation of bone, since it has been so frequently described by others, and I shall, therefore, refer to the accomplished result, rather than to the many changes by which it is reached.

Dr. Humphrey experimented on rabbits, and has described the sawn end of the bone as it appeared nine days after the performance of the amputation in the following words: "The end of the bone was covered by a layer of soft, granulation-like structure, which filled up the crevices in its edge, and was connected with the medullary membrane and periosteum."[1] This amputation was performed through the lower third of the femur on a rabbit which was only three weeks old; and although only nine days had elapsed, we are told by the experimenter, that the wound was healed and there was no pus. The same experimenter further reports that: "On July 23, 1860, I experimented on two pigs nine weeks old. 1. Amputation a little below the middle of the right thigh, which measured four inches and three-quarters. The stump healed quickly. The animal was killed February 2, 1861. . . . . The medullary canal is closed below by a layer of hard bone continuous with the wall of the shaft. The lower end is rounded off, except at the posterior part, where a process of bone, about three lines in length, projects downward from it. It was involved in tough, fibrous tissue, and thus covered, projected into a bursa-like cavity, lined by tough membrane, with fibrous processes hanging into it. . . . 2. Amputation a little below the middle of the right leg, which measured four inches and a quarter. Stump healed quickly. The animal was killed February 2, 1861. . . . . Its lower end was covered with tough, fibrous tissue. The medullary canal is closed by a thin, transverse sheet of bone, and a ring-like process of bone projects from the surrounding wall, two lines below the level of this septum."[2] These experiments are

[1] Ibid. p. 129. [2] Ibid. p. 131.

quoted for the purpose of illustrating the structural changes which occur in the sawn end of the bony stump after the performance of an amputation, and here we have observed that the medullary opening is soon filled up with a soft granulation substance, which also completely covers the end of the bone, and furthermore, that this material is finally changed into bone. In this manner the bone is rounded up and its sharp edges completely eradicated. It occasionally happens by the same process that the end of the bone is even enlarged, possessing a diameter greater than the bone of the healthy extremity at a corresponding point; and should the stump be formed of two bones, they are approximated, and sometimes joined together by an osseous arch, but more commonly the union is ligamentous. Covering this bony structure of the stump there is a dense fibro-cellular texture and scattered nervous fibrillæ, and the vessels are obliterated up to the nearest collateral branch. The accompanying illustration (Fig. 139), is intended to represent the structural changes which occur in the bony stumps after the performance of an amputation. Having examined briefly the subject of stumps, we are now prepared to enter on the consideration of

Fig. 139.

Artificial Limbs,

which has not in England or America received that attention to which it is entitled from the medical profession. The works on surgery in the English language are singularly deficient in this respect, containing only a few meagre facts, wholly insufficient to prepare the surgeon to make an intelligent selection of an artificial limb for a patient, or even to study the advantages and disadvantages of a particular kind of stump with reference to prosthesis.

The mechanism, durability, cost, and efficiency of an artificial limb are important matters to the maimed, and the attending

surgeon should be prepared to answer any question on these, and many other allied topics, since the patient's happiness, as well as much of his usefulness, depends on the intelligence employed in the selection and application of the artificial limb. The social position occupied by the maimed is another element which must be carefully considered in this connection. The opulent have a right to demand and receive the best which money will buy, and, consequently the artificial limb selected for him should be that one which most completely hides the deformity, and at the same time enables him to perform all necessary movements with the highest degree of grace and ease. We now recognize the fact that artificial limbs are employed for a double purpose, the relief of deformity and the restoration of power, or, in other words, to hide an unsightly disfigurement, and to enable the maimed to perform many sorts of labor with the same readiness as before the receipt of the injury.[1] Either upper extremity may be lost without compelling the unfortunate patient to procure an artificial limb, but when both are removed, then it becomes almost imperative that he should obtain mechanical substitutes in order that he may be able to care for his body and provide for his natural wants. The loss of a lower extremity compels the maimed to procure a substitute in order that he may resume locomotion, which is essential for the preservation of his health, and more or less necessary in the prosecution of any occupation. Having this brief introduction of the subject before us, we will now turn to its history.

THE HISTORY OF ARTIFICIAL LIMBS may be said to date from the commencement of the sixteenth century, although Pliny speaks of an artificial hand which was made and worn by M. Sergius long before this period, and with which he certainly rendered most heroic service. The original text reads as follows: "M. Sergio, ut equidem arbitror, nemo quemquam hominum iure praetulerit, licet pronepos Catilina gratiam nomini deroget. Secundo stipendio dextram manum perdidit,

[1] The remainder of this chapter is essentially a translation from the "Arsenal de la Chirurgie Contemporaine," by Gaujot et Spillmann, tome ii., Paris, 1872.

. . . . dextram sibi ferream fecit, eaquereligata proeliatus Cremonam obsidione exemit."[1] It having been changed into our own vernacular, reads thus: I suppose every one would admit that M. Sergius, the great-grandson of Catiline, had not diminished the fame of his name, since he lost his right hand in his second campaign. . . . He made himself an iron right hand, and with this fastened on, having fought a battle, he released Cremosea from siege. The distinguished Chevalier Goetz fought at the head of the army of Margrave Frederick from 1504 to 1562 with an artificial iron hand. Figs. 140, 141, and 142 show this historic hand and its internal mechanism.

Fig. 140.

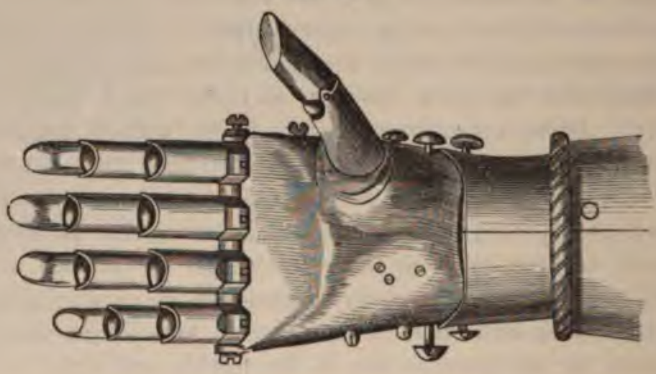


Fig. 141.

Fig. 142.

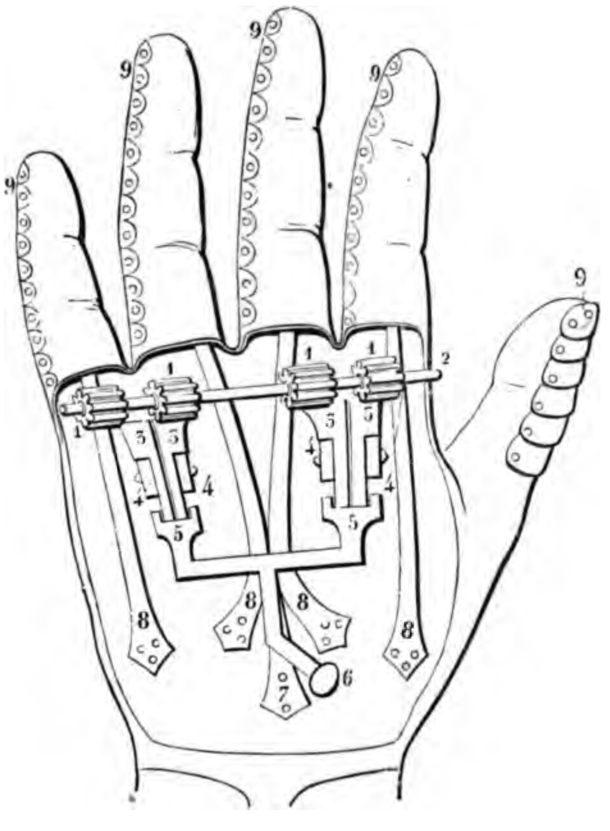
Fig. 140 represents the external appearance of the artificial iron hand, whilst Figs. 141 and 142 are intended to show its

[1] C. Plini Secundi Naturalis Historiæ, edidit Carolus Mayhoff, vol. ii. Libri vii. p. 26.

internal mechanism, including that of the fingers. We are further informed that this hand, which possessed enormous weight, inclosed the stump and was attached to the armor which covered the body.

During the sixteenth century many artificial limbs were manufactured, but they were very imperfect and could only be moved by the aid of the well hand. These defective artificial limbs however served the purpose for which they were intended,

Fig. 143.



since the maimed were enabled to engage in battle, to guide their horses, etc. The artificial hand being once properly

attached to the weapon or the bridle rein, there was no necessity for movable articulations in the fingers. The artificial hand which was figured and described by Ambrose Paré was also made of iron, but its mechanism was more perfect than the one which has been previously mentioned. Paré's artifical hand is shown in Fig. 143.

Here the thumb is immovable and the fingers are endowed with the power of protrusion. In the hand of Chevalier Goetz the fingers are closed one after the other by the action of several springs, but in the hand of Paré all the fingers are opened and closed simultaneously under the influence of a single spring.

During Ambrose Paré's time an effort was made to restore the natural movements of the lost parts, in order to enable the maimed to perform all ordinary labor, and especially to enable him to write. The iron hand had proven objectionable, and there were now attempts made to substitute for this metal, leather, paper, etc. The leather hand has been erroneously accredited to Gavin Wilson. Ambrose Paré has left to us on this subject a very interesting figure of a useful leather hand, although there is much uncertainty in regard to the inventor. No details of

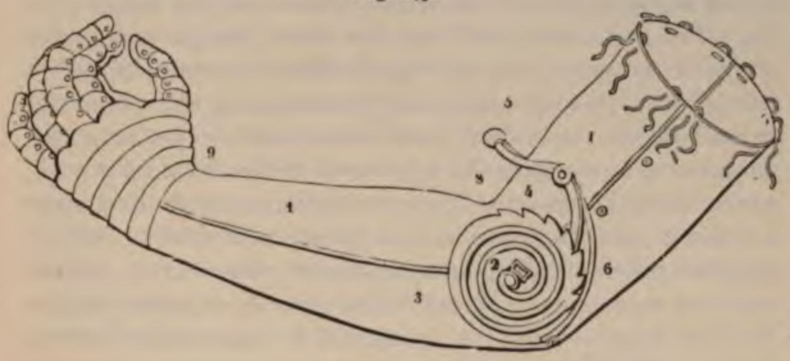
Fig. 144.

the mechanism of the hand are given, but the figure plainly indicates that the fingers were fixed in an unchangeable position. There is a sheath between the thumb and index finger, intended to receive the pen which could be removed at will. The stump

is pushed as far as possible into the leather hand and is here attached to the sleeve by means of the holes shown in Fig. 144.

Ambrose Paré gives the first description of an artificial forearm. The apparatus is shown in Fig. 145, and was made by

Fig. 145.



Lorrain. It is easily seen that the maimed, by the assistance of the sound hand, is enabled to bring the artificial limb into any convenient degree of flexion, and to maintain it there, by means of the catch, which is caught in the meshes of the cog wheel.

The hand which is attached to this apparatus has already been described, and is represented in Fig. 143. The crippled was enabled to handle his weapons with the right hand, which remained intact, and in the mean time he holds the reins of his horse in the artificial hand.

The artificial limbs described by Ambrose Paré seem to have been in favor until the latter part of the eighteenth century. At this time, a monk of the order of Carmelites, Father Sebastian, cited by Dionis, had made considerable progress in the prosthesis of the superior extremity by conceiving a hand with movable articulations independent of assistance from the healthy hands, an improvement which many other authors accredited to Baillif. The apparatus of Father Sebastian was made of sheet-tin, and contained several springs. The movements of the stump caused these springs to act in such a manner as to put in motion the thumb and fingers. This improvement was not sufficient, since

the apparatus of Father Sebastian and his successors was too complicated, although it could be advantageously employed in those cases where the forearm had been amputated near to the wrist-joint. The amputations in the upper part of the forearm, and for still stronger reasons amputation of the arm, still continued to employ Paré's apparatus, which was only movable by the aid of the sound hand or some other foreign power, and above all excessively heavy. Garvin Wilson is said by B. Bell to have remedied the latter inconvenience by making an artificial arm of hard leather which was covered with colored sheep-skin in such a manner as to represent the appearance of the human skin; and, to render the deception still more complete, he made the nails of white horn, and painted them so as to represent nature. The articulations of the fingers, the hand, and the elbow were combined in such a manner as to permit the movements of flexion, extension, and rotation under the direction of the other hand. Wilson placed in the palm of the hand an iron screw, which was intended to receive a knife or fork. A leather ring or sheath was placed between the thumb and index finger for the purpose of receiving the pen, the same as had been previously employed in the leather hand of Ambrose Paré. Wilson's hand was praised beyond measure by B. Bell, and although the improvements to it were mainly to its external appearance without adding any important modifications to its mechanism, *i. e.*, to its essential parts. De Graefe suggested, in 1818, a mechanical procedure, which is followed with but slight modification in the manufacture of nearly all the artificial arms in our day. De Graefe suggested, in fact, the idea of constructing an artificial arm susceptible of spontaneous movements, accomplished by springs, or more frequently by catgut strings attached to a corset surrounding the shoulders and thorax. In this system, even after the amputation of the arm, the artificial limb should be moved at will by the play of the muscles of the trunk or shoulders without the assistance of the other hand. The first application of this principle was made by Baillif and Van Petersen. Since this period, the prosthesis of the upper extremity has made new progress every

day by studying to adopt the artificial limb to all the peculiarities of the stump, of the length, etc.

Incomplete Amputation of the Hand.

The occasion for the application of an artificial apparatus in cases of partial amputation of the hand are not frequent, especially as surgeons tax their ingenuity to perform operations in such a manner as to leave as much as possible of this precious organ. It is seldom that a cripple desires an artificial limb so long as he has the free use of the thumb, because with this he may very readily oppose it to any remaining portion of the fingers, or even of a stump constituted of a more or less extended part of the metacarpal bones; he can thereby seize objects with the required delicacy. If, in the mean time, the metacarpal bones have been wholly removed, the thumb could be brought with much difficulty in contact with the carpal bones, and, consequently, under these circumstances, it would be advisable to add a piece to the stump in order to facilitate prehension. The most simple means consists in placing the stump in a leather or wooden sheath, which should terminate in immovable fingers that are slightly flexed. The sheath should be fastened to the forearm. Such an apparatus renders the greatest service, and the study of Beaufort's artificial arm, which is constructed on the principle of the mobility of the thumb alone, while the fingers remain immovable, should convince any one of its utility. The prosthesis of the thumb is of the highest importance, because

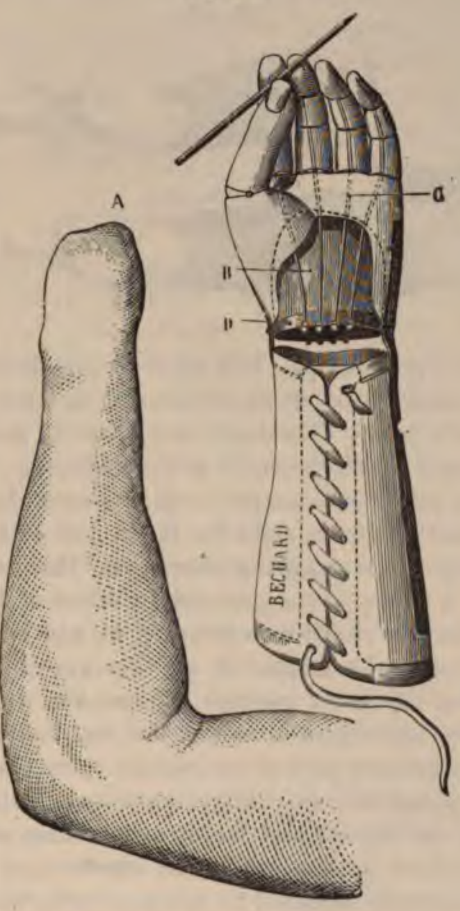
Fig. 146.

the free movements of this member which bring it in contact with the fingers are indispensable in packing up or handling delicate objects. Divers cases may present themselves here; if only the second phalanx is absent, if even the first has been amputated in its continuity, nothing is more easy than to adapt to the stump a wooden phalanx, the anterior surface of which should be covered with a double layer of leather in order to render more pleasant its contact with the index finger. This phalanx covered with a leather sheath, and adjusted in the style of the thumb of a glove, is seen in Fig. 146, which represents an artificial thumb made by Mathieu. Here the prosthesis ought to be perfect, because the artificial thumb preserves all its natural movements. An analogous apparatus ought to be applicable in cases of loss of both phalanges of the thumb, the results all being less complete, only possessing a certain degree of utility, since the artificial thumb would follow the movements of the first metacarpal bone to which it is attached. If the entire thumb has been removed, *i. e.*, if the loss of substance included the metacarpal bone, it will be necessary to abandon the idea of obtaining motion in the artificial substitute. Under these circumstances, the artificial thumb should be placed in a state of semi-adduction, in which position the index and fore-fingers may be readily brought in contact with it. Sometimes all the fingers and the thumb have been amputated at the metacarpo-phalangeal articulation.

Fig. 147 represents an apparatus applied by Bechard. The stump is surrounded by a leather sheath, *B*, moulded on itself, and extends upward to the wrist where it is bordered with a steel band, *D*; thus secured, it is introduced into a wooden hand which is bound to a laced armlet on the forearm. The wooden hand terminates in articulated fingers, the mobility of which is assured by catgut strings, *C*, which are fastened at the upper extremity around the steel band. The movements of flexion and extension of the stump on the forearm determine, in the tension of the cords, the changes which excite in their turn the flexion and the extension of the fingers. In respect to the thumb, it is immovable in the position of adduction which

permits the index and forefingers to come in contact with it. It has been justly claimed that it would be useful to place at the base of the thumb two little mortises, in which the artificial member might rest when it is at repose in different degrees of

Fig. 147.



adduction, the shape of the hand being thus rendered more natural. The apparatus of Bechard, however ingenious it may be, is a luxury which the laborer should abandon for some more useful instrument, its only value being in its enabling the pos-

sessor to hold a pen, paper, etc. During the winter of 1869, Mathieu constructed a much less elegant instrument, but one with which a laborer may perform much hard work. This apparatus, shown by Fig. 148, consists simply of a metal plate, *B*, placed on the anterior surface of the forearm, and extending

Fig. 148.

downward to the stump. This plate is attached to a leather sheath, *A*, which surrounds the forearm on which it is bound by the means of a lace. This sheath is fastened to the band, *E*, by a leather strap which prevents it from slipping. The stump composed of all the metacarpal bones possesses the movements of flexion and extension, since the flexor and extensor muscles have contracted with secondary adhesions. This principle being understood, it is easy to comprehend the action of the apparatus; when the stump is raised it is possible to slip between it and the metal splint the handle of any instrument, a shovel, for example, then the flexor muscles act, and the more firmly the handle of the instrument is seized, the less liable will it be to slip from the anterior part of the metallic splint. We have seen a laborer supplied with this simple apparatus continue to earn a good living for himself and family as a fireman on an engine. Two orifices have been made in the anterior part of the splint at *D* and *C*; one is intended to receive a fork, the other a pen, pencil, etc. The handle of the instrument slips beneath the stump, and is provided with a good point of support at the commissure which separates the thumb from the second metacarpal bone.

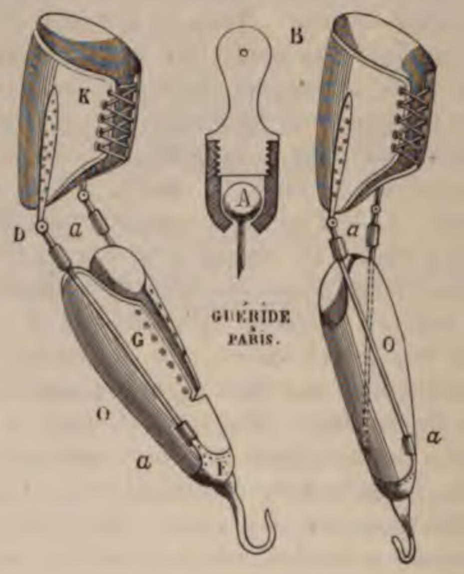
Disarticulation at the Wrist and Amputation of the Forearm.

At all times, the maimed have surrounded their stumps with cushions of certain solidity, capable of protecting them against cold and external violence. They are not slow to comprehend that these cushions may render the most important service if they can be made to support different instruments. All the world knows the history of the invalid, who, in order to support himself, inclosed his right forearm in a wooden case, in which different openings were made to receive a flute, hook, and a pair of forceps. L. V. Lagneau mentions a general who played perfectly on a violin, by adapting to the mutilated forearm a jointed elastic metal sheath to which was soldered the fiddle-bow. The artificial forearms manufactured in our day are divided into two grand classes; the serviceable forearm for workmen and the luxurious forearm, which aims to hide the deformity, for the wealthy. The laborer's forearm is generally composed of a leather sheath, *G*, which surrounds the stump and terminates below in a metallic shield or cap; *E*, pierced in its centre for the reception of a screw. Superiorly this leather sheath is united to a band, *K*, which is laced on the arm, and is intended to prevent the cover of the stump from slipping. This apparatus is shown in Fig. 149.

If the forearm has been amputated very close to the wrist, the covering of the stump may be fastened to the ring by a simple leather strap, which has the advantage of permitting flexion and extension without hindering pronation. If the forearm has been amputated near the middle, it will then be necessary to substitute metallic splints for the leather straps articulated at the elbow-joint. It is generally thought sufficient to articulate these splints by a simple bolt on which they turn during the flexion and extension, but then pronation and supination are lost. Guéride has invented an excellent apparatus which has not this inconvenience. The splints, *O*, run along the side of the stump cover and terminate above and below by a small ball represented by *a* in Fig. 149. This ball, *A*, is movable,

working smoothly in the small cavities in the upper and lower part of the stump covering. The splints, thus jointed, we find to be composed of thin pieces which turn on themselves, permit-

Fig. 149.



ting all the necessary movements of pronation and supination. In *D* the splint on the forearm is united to the humeral splint in

Fig. 150.

the ordinary way for flexion and extension. The instrument most frequently fitted to the hollow cap at the lower extremity of the apparatus is the hook, which is so useful to laborers in

carrying burdens, pulling objects, etc. A knife, fork, hammer, paper-holder, or a pencil-case may be substituted for this hook. In all these instruments the screw is of the same size, in order that the one may be substituted for the other. In some instances a square opening in the lower part of the stump covering is substituted for the screw aperture, and in these cases the instruments are kept in place by a spring. Guéride's apparatus and the various implements employed by the same are shown in Figs. 149 and 150.

We fully comprehend that all these instruments may be managed with great precision by the forearm which possesses the movements of flexion, extension, supination, and pronation, that it is only a matter of habit. The farmer must labor with the plow, shovel, and pickaxe, and these instruments require for their management the use of both hands, and consequently require other appendages. The senior Charrière constructed a long time ago an instrument of great simplicity, which seems to us to accomplish its object perfectly, and is shown in Fig. 151.

Fig. 151.

At the extremity of the covering of the stump, *A*, Charrière screwed down instead of a hook a metal stem supporting at its extremity a leather cylinder, *B*, which is surrounded by two leather straps supplied with buckles, permitting it to be tightened at will. Supposing the handle of a shovel to be fixed in this cylinder near to its free extremity, the hand seizes the handle by its opposite extremity, *i. e.*, at a point more or less nearly approaching to the shovel, and makes the required movements for the kind of work which the maimed wishes to perform. The shovel is now easily directed, when the stem which supports the cylinder is jointed in its central part, permitting it to be extended and flexed under the impulse which it receives from the hand, which is placed in the central part of the handle. Still remember that this stem possesses certain movements of rotation, because nothing prevents it from mak-

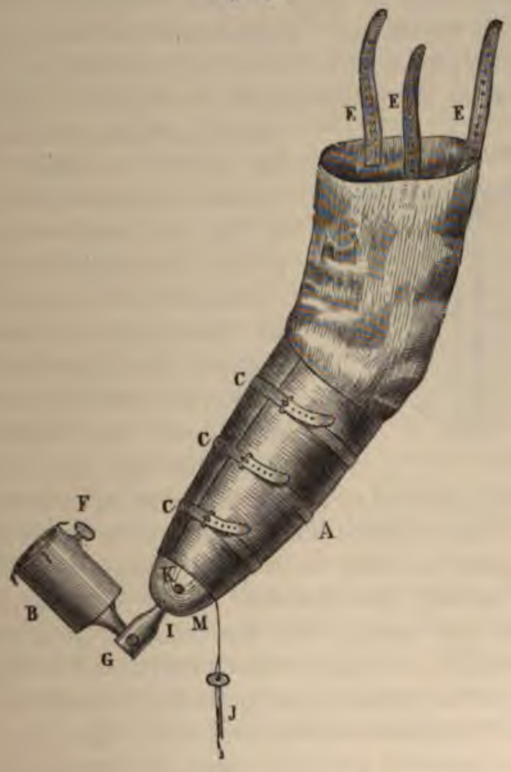
ing a semicircle where this is required of the instrument. This movement of rotation is considerable; it is true it does not exceed a semicircle, but it is useless that it should be otherwise, because the management of agricultural instruments does not require a more extended movement. Furthermore, this same rotation only becomes indispensable where the natural movements of pronation and supination no longer exist; however, this is of rather frequent occurrence, since the radius and ulna are frequently firmly bound together after amputations.

In order to prevent this accident, which is very prejudicial when examined with reference to prosthesis, Lenoir has advised placing on each aspect of the forearm a graduated compress as is commonly practised in the treatment of fractures. Instead of the leather cylinder Mathieu employs a very firm metallic ring, *E*, which may be fastened to the cover of the stump by a simple foot screw, the same as the hooks (see Fig. 167).

The opening in this ring should be a little larger than the handle of the agricultural instrument which it is intended to encircle. The manner of employing this apparatus is very simple: the handle of the instrument is carried through the ring, then the free extremity of the handle is seized by the uninjured hand. The handle of the instrument is raised, the ring is thrown to one side, and is held there by the resulting pressure arising from its inclination. The shovel, for example, is pushed into the earth to be raised again; at the moment of lifting it up the possessor of the artificial limb perceives that he would have more power by seizing the handle of the instrument at a different point from that at which it was placed originally in the ring; and this change is readily effected by a slight movement of the stump which causes the handle to slip in the ring until it occupies the most convenient position. The possibility of completely changing the position of the ring in a second by an easy and rapid movement, secures to this instrument a considerable advantage for the work which consists in displacing the earth, in loading sand carts, etc.; from this point of view it is superior to the leather cylinder. It is very easy to guide with it the

handle of the plow, to sink into the hard earth the pickaxe or shovel, and it is good when the handle of the instrument should be seized firmly, and in an unchangeable manner, although the cylinder might be preferred, or instead of these there might be employed, as is done by Mathieu, a metallic half-circular ring, the circumference of which is completed by a leather strap supplied with a buckle, which enables it to be tightened at will. The handle of the hammer and other similar instruments are fixed in a sort of vise by a screw, *H* (see Fig. 167). However,

Fig. 152.



nothing is more easy than to adapt these various appliances to the same stump cover.

Dr. Gripouilleau constructed, in 1861, an artificial arm and

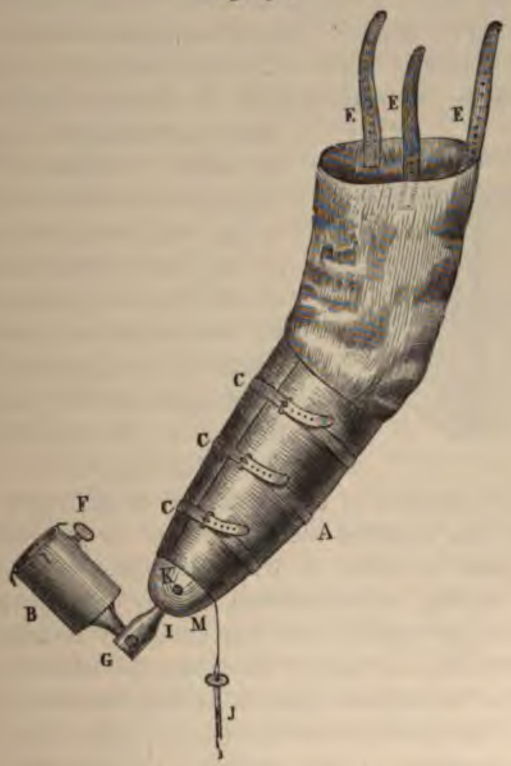
ing a semicircle where this is required of the instrument. This movement of rotation is considerable; it is true it does not exceed a semicircle, but it is useless that it should be otherwise, because the management of agricultural instruments does not require a more extended movement. Furthermore, this same rotation only becomes indispensable where the natural movements of pronation and supination no longer exist; however, this is of rather frequent occurrence, since the radius and ulna are frequently firmly bound together after amputations.

In order to prevent this accident, which is very prejudicial when examined with reference to prosthesis, Lenoir has advised placing on each aspect of the forearm a graduated compress as is commonly practised in the treatment of fractures. Instead of the leather cylinder Mathieu employs a very firm metallic ring, *E*, which may be fastened to the cover of the stump by a simple foot screw, the same as the hooks (see Fig. 167).

The opening in this ring should be a little larger than the handle of the agricultural instrument which it is intended to encircle. The manner of employing this apparatus is very simple: the handle of the instrument is carried through the ring, then the free extremity of the handle is seized by the uninjured hand. The handle of the instrument is raised, the ring is thrown to one side, and is held there by the resulting pressure arising from its inclination. The shovel, for example, is pushed into the earth to be raised again; at the moment of lifting it up the possessor of the artificial limb perceives that he would have more power by seizing the handle of the instrument at a different point from that at which it was placed originally in the ring; and this change is readily effected by a slight movement of the stump which causes the handle to slip in the ring until it occupies the most convenient position. The possibility of completely changing the position of the ring in a second by an easy and rapid movement, secures to this instrument a considerable advantage for the work which consists in displacing the earth, in loading sand carts, etc.; from this point of view it is superior to the leather cylinder. It is very easy to guide with it the

handle of the plow, to sink into the hard earth the pickaxe or shovel, and it is good when the handle of the instrument should be seized firmly, and in an unchangeable manner, although the cylinder might be preferred, or instead of these there might be employed, as is done by Mathieu, a metallic half-circular ring, the circumference of which is completed by a leather strap supplied with a buckle, which enables it to be tightened at will. The handle of the hammer and other similar instruments are fixed in a sort of vise by a screw, *H* (see Fig. 167). However,

Fig. 152.



nothing is more easy than to adapt these various appliances to the same stump cover.

Dr. Gripouilleau constructed, in 1861, an artificial arm and

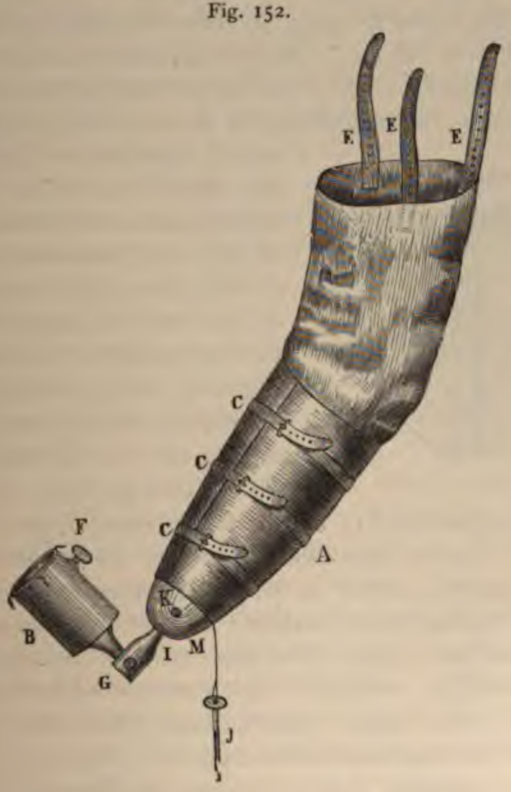
ing a semicircle where this is required of the instrument. This movement of rotation is considerable; it is true it does not exceed a semicircle, but it is useless that it should be otherwise, because the management of agricultural instruments does not require a more extended movement. Furthermore, this same rotation only becomes indispensable where the natural movements of pronation and supination no longer exist; however, this is of rather frequent occurrence, since the radius and ulna are frequently firmly bound together after amputations.

In order to prevent this accident, which is very prejudicial when examined with reference to prosthesis, Lenoir has advised placing on each aspect of the forearm a graduated compress as is commonly practised in the treatment of fractures. Instead of the leather cylinder Mathieu employs a very firm metallic ring, *E*, which may be fastened to the cover of the stump by a simple foot screw, the same as the hooks (see Fig. 167).

The opening in this ring should be a little larger than the handle of the agricultural instrument which it is intended to encircle. The manner of employing this apparatus is very simple: the handle of the instrument is carried through the ring, then the free extremity of the handle is seized by the uninjured hand. The handle of the instrument is raised, the ring is thrown to one side, and is held there by the resulting pressure arising from its inclination. The shovel, for example, is pushed into the earth to be raised again; at the moment of lifting it up the possessor of the artificial limb perceives that he would have more power by seizing the handle of the instrument at a different point from that at which it was placed originally in the ring; and this change is readily effected by a slight movement of the stump which causes the handle to slip in the ring until it occupies the most convenient position. The possibility of completely changing the position of the ring in a second by an easy and rapid movement, secures to this instrument a considerable advantage for the work which consists in displacing the earth, in loading sand carts, etc.; from this point of view it is superior to the leather cylinder. It is very easy to guide with it the

handle of the plow, to sink into the hard earth the pickaxe or shovel, and it is good when the handle of the instrument should be seized firmly, and in an unchangeable manner, although the cylinder might be preferred, or instead of these there might be employed, as is done by Mathieu, a metallic half-circular ring, the circumference of which is completed by a leather strap supplied with a buckle, which enables it to be tightened at will. The handle of the hammer and other similar instruments are fixed in a sort of vise by a screw, *H* (see Fig. 167). However,

Fig. 152.



nothing is more easy than to adapt these various appliances to the same stump cover.

Dr. Gripouilleau constructed, in 1861, an artificial arm and

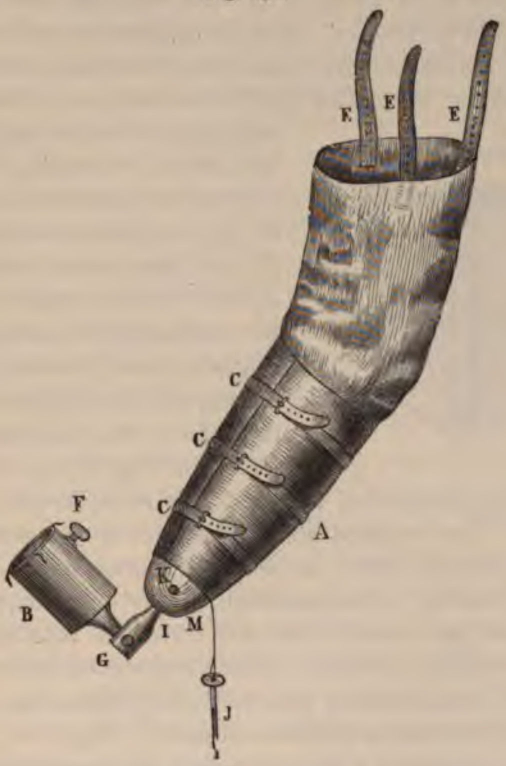
ing a semicircle where this is required of the instrument. This movement of rotation is considerable; it is true it does not exceed a semicircle, but it is useless that it should be otherwise, because the management of agricultural instruments does not require a more extended movement. Furthermore, this same rotation only becomes indispensable where the natural movements of pronation and supination no longer exist; however, this is of rather frequent occurrence, since the radius and ulna are frequently firmly bound together after amputations.

In order to prevent this accident, which is very prejudicial when examined with reference to prosthesis, Lenoir has advised placing on each aspect of the forearm a graduated compress as is commonly practised in the treatment of fractures. Instead of the leather cylinder Mathieu employs a very firm metallic ring, *E*, which may be fastened to the cover of the stump by a simple foot screw, the same as the hooks (see Fig. 167).

The opening in this ring should be a little larger than the handle of the agricultural instrument which it is intended to encircle. The manner of employing this apparatus is very simple: the handle of the instrument is carried through the ring, then the free extremity of the handle is seized by the uninjured hand. The handle of the instrument is raised, the ring is thrown to one side, and is held there by the resulting pressure arising from its inclination. The shovel, for example, is pushed into the earth to be raised again; at the moment of lifting it up the possessor of the artificial limb perceives that he would have more power by seizing the handle of the instrument at a different point from that at which it was placed originally in the ring; and this change is readily effected by a slight movement of the stump which causes the handle to slip in the ring until it occupies the most convenient position. The possibility of completely changing the position of the ring in a second by an easy and rapid movement, secures to this instrument a considerable advantage for the work which consists in displacing the earth, in loading sand carts, etc.; from this point of view it is superior to the leather cylinder. It is very easy to guide with it the

handle of the plow, to sink into the hard earth the pickaxe or shovel, and it is good when the handle of the instrument should be seized firmly, and in an unchangeable manner, although the cylinder might be preferred, or instead of these there might be employed, as is done by Mathieu, a metallic half-circular ring, the circumference of which is completed by a leather strap supplied with a buckle, which enables it to be tightened at will. The handle of the hammer and other similar instruments are fixed in a sort of vise by a screw, *H* (see Fig. 167). However,

Fig. 152.



nothing is more easy than to adapt these various appliances to the same stump cover.

Dr. Gripouilleau constructed, in 1861, an artificial arm and

forearm which commends itself by its simplicity, as will be seen by an examination of Fig. 152, with which we will occupy ourselves only for a moment. It is composed of a leather sheath which may be tightened at will by the leather straps, *C C C*; this sheath terminates above in an armlet of strong ticking, *D*, which is attached to a shoulder-piece, *C*, by the means of ticking straps, *E E*, while the shoulder-piece (see Fig. 168), is fastened to the belt, *F*, by two suspenders, *D*, the one passing down in front and the other behind the chest. There are two other straps which are passed around the thigh and attached to the girdle which encircles the waist to keep it from slipping up during the movements of the laborer. This arrangement secures great firmness of the sheath, *A*, which is attached inferiorily to round pieces of black walnut, *m*, in which plays the armature, *I*, which terminates in a socket, *B*, and performs the office of a hand. The piece of black walnut which is represented in Fig. 153, shows the appearance of this piece after having been divided into two equal parts, and we observe that it is crossed in the centre by two grooves, one longitudinal and the other narrower and transverse. The armature (represented in Fig. 170), is made of iron, and is composed of two parts, the stem, *B*, and the bifurcation, *C*. The rounded stem is placed in the groove of the rounded piece of wood in which it turns freely, its upper extremity having been flattened out in order to prevent its escape from the canal. The movement of rotation may be arrested at will by the key, *J*, which introduced in the orifice, *K* (Fig. 152), of the rounded piece of wood, penetrating on its way the stem of the armature which crosses it (Fig. 170).

Fig. 153.

We have observed that this stem is traversed by two canals, arranged like a cross, in such a manner that the armature may be fixed in several different positions, according as the key crosses the one or the other of these canals. The bifur-

cation of the armature is only used in amputations of the arm, although, if employed in amputation of the forearm, the stem, *B*, terminates simply by a little cavity which incloses a ball that is found at *G* (Fig. 152), at the posterior part of the socket which turns in every direction on the armature. This socket performs the office of a hand, and is four centimetres in diameter and six centimetres in length. It receives into its interior the handle of the agricultural implement which is fixed by the pressure screw, *F*. At the circumference of this socket are places for two little hooks with which the maimed may draw objects, push aside stones, etc. The advantages of this apparatus are the facility with which it seizes, the mode of articulation of the socket, and the armature permits an agricultural instrument to take all the positions which are given to them by the healthy hand which holds one of its extremities. For certain kinds of work, such as the management of the scythe or hammer, the movements of the socket are more injurious than beneficial; but nothing is more easy than to arrest this motion by introducing a small key into the surface of the articulation. Gripouilleau's apparatus for amputation of the forearm has nothing very new about it. All the principles are found in the artificial forearm manufactured by Charrière, and in the meanwhile its value is incontestable. This value arises from the fact that it may be constructed by workmen of ordinary skill; a village harness-maker and wheelwright, and that too at an exceedingly moderate price. Gripouilleau has in fact had it made by mechanics in Mount Louis, of which he is the physician, for the moderate sum of twenty francs. We ourselves generally carefully abstain from raising the money question in this work, but here it is capital, since the apparatus under consideration is intended for the poor. The most valuable forearm for the workingman would be perfectly worthless if the price be too high. We add here that the apparatus of Gripouilleau, the artificial appliance which we now recommend in cases of amputation of the arm, belongs to the public domain, because the physician, animated solely by a desire for its usefulness, has abstained from taking a patent.

Many unfortunates who have lost a portion of a limb are desirous of obtaining an artificial substitute which will permit them at the same time to perform certain kinds of work and likewise hide the deformity. The artificial forearm of Gripouilleau will not answer this purpose. In such cases it is necessary to have recourse to a forearm with a ring, fork, cylinder, or such other implements as may be required for the occasion, and when they are no longer required for actual service, their place is taken by an an artificial hand. Samson has made this hand of linden wood, which is very light. The phalanges of the fingers were united at their articulations tightly enough to preserve any position in which they were placed by the sound hand. The hand of Charrière is more complicated. The mechanism of Samson's is limited to the articulations of the fingers, wrist, and the sheath which covers the stump. The thumb, index, and forefinger are placed under the constant influence of a spring which keeps them shut, and light objects may be held between these fingers. It is more important that a spring should be placed on the inner

Fig. 154.

side of the articulation of the wrist, which enables the hand to be placed at different degrees of pronation and supination.

Fig. 155.

We observe in Fig. 154, that both the elastic springs are designed to favor the movements of flexion of the forearm; these

springs are very useful when the stump has considerable length. These artificial hands are little more than articles of luxury; in the meanwhile it is possible to render them most useful by employing the contrivances of Beggs, of which some examples have been previously mentioned.

Fig. 155 represents a hook fixed in the palm of the hand by a spring which the possessor is enabled to raise or lay down at

Fig. 156.

will. The possession of this hand would be more inconvenient than useful to a laborer; but it might be serviceable to the

Fig. 157.

wealthy class. Figs. 156, 157, and 158 show the uses for which these hooks may be employed by modifying their forms.

A fork may be held in the palm of the hand, a pen between the thumb and index finger, etc. All these artificial hands are constructed according to the principles known during the fifteenth century, and their articulations are only able to act under the influence of the sound hand. It is, however, true that their mechanism is now more simple than it was during the early history of artificial limbs and they are also made extremely light. Samson's hand weighs only 125 grammes, although that of Paré's weighed 1500. It is true that the wants have changed; in the time of Paré the artificial hand was especially destined for war, but in our day the maimed are especially anxious to be able to hold a pen, pencil, etc. The manufacturer of artificial limbs ought never to be content with these elementary proceedings. He should endeavor to produce artificial limbs in which the articulations are made susceptible of spontaneous movements. This object is probably attainable, but it seems to be beyond the ingenuity of the present century, although it should not be forgotten that attempts were made to accomplish it during the past. In 1818 the first really useful forearm of this kind made its appearance, and was constructed by Baillif, of Berlin. This apparatus is shown in Fig. 159, and was construeted according to the views put forth by Graefe.

Fig. 158.

An anti-brachial sheath, *A*, surrounds the forearm and terminates in an artificial hand. All the articulations are movable and are maintained in permanent flexion by strong spiral springs which pass from one phalanx to another. The action of these springs is combined in such a manner as to firmly close the fist when the apparatus is in a state of repose. The extension is produced by means of catgut cords, which, starting from the dorsal surface of the four fingers, are attached to the inferior

border of the triangle of Laiton situated in the carpal cavity. The apex of the triangle, turned to the side of the arm, received by the intermediation of a ring the attachment of a new cord of catgut, fixed to the string *G*, which after having surrounded the

Fig. 159.

shoulder is fastened by the string, *F*, to the band, *D*, surrounding the thorax. When the arm is raised the catgut cord is rendered taut and the fingers are opened. A catgut cord, *E*, destined to move the thumb is attached directly to the belt. The length of this cord is such that the thumb is opened before the fingers. The cords passing over the apparatus are enveloped in sheaths, which hide them from view, and a leather glove covering the artificial hand contributes much to concealing the deformity. The apparatus of Baillif certainly constitutes an immense progress, but it still has the inconvenience of being very compli-

cated, weak, and at the same time very heavy. It was difficult for a long time to write or sew with an arm, the handle of which alone weighed 500 grammes. More recently a Dutch mechanic, Van Petersen, constructed a very light apparatus, in which the fingers were also extended by a catgut cord and flexed by springs.

Fig. 160.

A sheath of very light wood incloses the stump, and is held in place by two bracelets numbered 5 and 6, which are shown in Fig. 160. 5 surrounds the lower part of the arm, and it is to this that the draught cord 10 is attached which puts the fingers in motion. The extension of the fingers is consequently effected at the same time as the extension of the stump. The motor principle adopted by the Dutch mechanic is very simple, and is calculated to render very valuable service when the stump is long enough, and especially when it is endowed with sufficient force to combat properly the power of the springs which produce the flexion of the fingers. It is necessary to remark in fact that these springs should possess sufficient power to seize and properly hold objects. The artificial forearm is constructed to-day on this principle, but the mechanism of the hand has been simplified by causing the catgut cord to act entirely on the thumb, index and forefinger; the ring and little fingers being only moved in this articulation by friction.

Charrière, Sen., has designed, for the prosthesis of the forearm a mechanism which is not based, as in the preceding, on the elevation of the arm, or on the movements of flexion and extension of the stump. Here, the movements of rotation of the forearm determine the extension or flexion of the fingers. The apparatus articulated at the elbow fits the shoulder and does not turn to the right or left along with the artificial hand. The lower portion of the stump is inclosed in a cushioned sheath which is firmly fixed to a stem placed in the hand. At the extremity of this stem are fastened the artificial contractor tendons of the

fingers. In communicating to the stump a movement from right to left, the stem draws on the artificial contractor tendons and the fingers are closed, enabling the maimed to hold an object; nevertheless he may slacken at will his grasp by turning his stump from the right to the left, because the stem pushes back the contractors which become extensors and cause the fingers to straighten out.

Count de Beaufort, a philanthropic foreigner, has constructed for a maimed pianist a right forearm, which is truly an apparatus of luxury and one that hides admirably the deformity. We reproduce the illustration and the description of this arti-

Fig. 161.

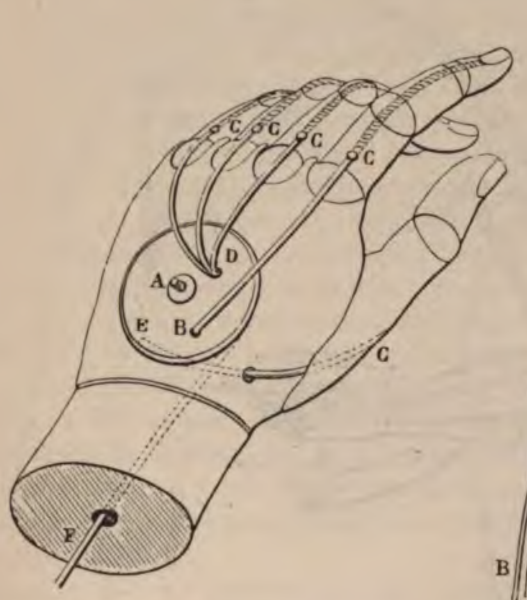
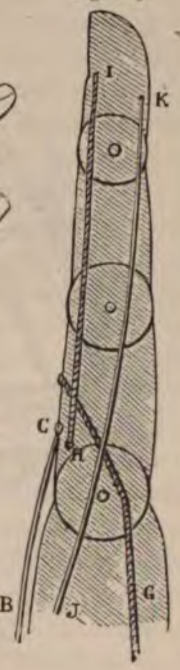


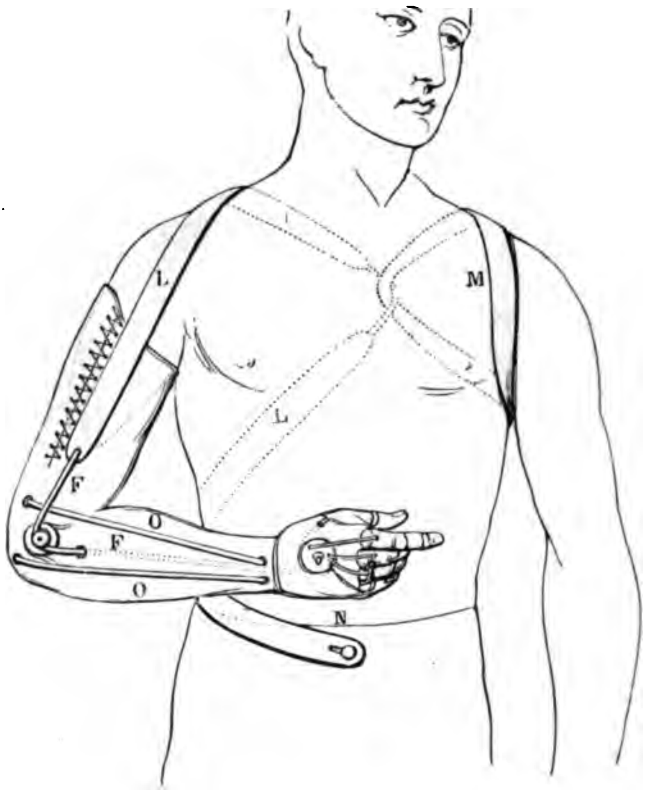
Fig. 163.



ficial forearm as given by de Beaufort, quoting word for word. The artificial hand is mounted on a pivot which is placed obliquely at the wrist; it therefore gives a complex movement of supination, because it raises itself at the same time that it is

drawn towards the body, and consequently this dispenses with a special movement for the production of rotation at the wrist. The fingers are maintained in a state of flexion by rubber springs which are placed in the thick part of the hand, and are fastened to the inner side of the wrist and the phalanges. Fig. 161 shows the cords of catgut, *B C* and *D C*, which are attached to the dorsal surface of the same phalanges, and are fixed to a

Fig. 162.



pulley, *A*, which receives the movements of the catgut cord, *F*. At this cord's end the motor leather strap, *L*, shown in Fig. 162,[1]

[1] This figure represents an amputation of the arm, but the original apparatus was made for an amputation of the forearm, and the cords, *O O*, are only employed in brachial amputations. We shall refer to it again.

is fixed at its opposite extremity to the button, *N*, placed on the front of the waist-band of the pantaloons, it slips in a loop, *M*, carried around the healthy shoulder, and then passing over the opposite shoulder is attached to the end already mentioned, and is rendered effectual by crossing the axis of the elbow and the centre of the wrist to the groove in the pulley, *A*. This disposition permits the utilization of the different movements of the body when the back is considerably arched outwards. When one wishes to open the hand, he enlarges the shoulders by taking a long breath which draws on the strap, *L*, in all its course; this preparatory condition is sufficient to produce an imperceptible movement of the shoulders or of the arm, and determines accordingly the play of the fingers; when, on the contrary, the body offers no resistance to the leather strap, the arm may make freely all the movements without, in the least, affecting the hand. It should be understood that the traction which we are about to describe causes the fingers to move through the intermediation of the pulley, *A* (see Fig. 161), and the cords, *B C* and *D C*, acting at first on the index finger by the cord, *B C*, which at its maximum tension rolls itself upon the pulley, *A*. There being no opposition, consequently the pulley continues to turn, The cord, *D C*, to which are attached the other fingers, operates in its turn in the same manner, and finally the thumb is involved in the same way by the continuation of the movements of the pulley by means of the attachment, *E C*. In this model I have given to the first phalanges of the fingers their normal length contrary to the custom that the articulations in the tiers are of the same length, and which establishes what they call the crooked phalanges, by reason of which the fingers in raising, present a broken or uneven appearance, *i. e.*, deformity.

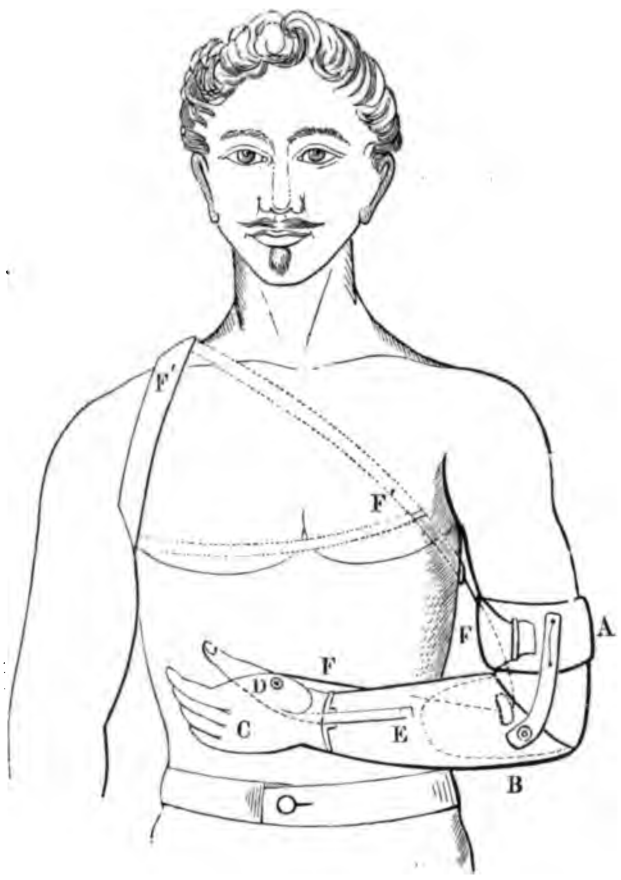
Fig. 163 shows a longitudinal cut of one of the fingers of de Beaufort's hand. *G* indicates the spring which flexes the fingers; *H I*, the spring tending to maintain the fingers in an extended position; *J K*, the catgut cord fixed by its extremities to the hand and the last phalanx. The apparatus which we are describing was designed by de Beaufort, and constructed by

Bechard, and the results produced by it are truly marvellous. It is possible with its assistance to vary the play of the fingers, to work successively the index, ring, and forefingers, and the thumb; to point out a person with a finger; to carry a light object, such as a hat; in a word, it is possible to conceal completely the deformity; but remember well, that to obtain all these results of intelligent force, it is only necessary that the maimed should play with his artificial arm as an artist plays on a piano. In fact this apparatus is only intended to be used by those persons whose sole object is to conceal the deformity. De Beaufort understood perfectly that such an invention could only be a convenience to a small number of individuals, and he was not slow to bring forward a more simple and at the same time a more serviceable apparatus. An artificial hand, whatever be its degree of perfection, plastic and mechanical, can only possess one useful quality, that of seizing objects like pincers, and this is easily comprehended. At all times when the natural fingers perform an act other than prehension, they are obliged to combine the action of flexion and extension with certain other lateral movements. Now the mechanic has not yet succeeded, and probably never will succeed, in combining together these different movements, consequently it is perfectly useless that the fingers of the artificial hand should be mobile, since it is positive that the power to grasp involves only two factors, therefore it is sufficient that the thumb should be able to be approximated and withdrawn from the fingers, and maintained in a permanent state of light flexion. This principle is perfectly applied in de Beaufort's artificial forearm with rigid fingers, and a movable thumb, which is shown in Fig. 164.

This apparatus consists of a band, *A*, and a sheath, *B*, joined together by means of two leather straps or two metallic splints. The sheath, *B*, terminates in a very light linden wood artificial hand, *C*, in which all the fingers are lightly flexed in an immovable position. The articulated thumb, *D*, is maintained in a constant state of pressure against the index and forefingers by a rubber spring, *E*, fixed to the thumb by one of its extremities and to the anti-brachial sheath by the other. A traction cord,

F F F, starting from the external surface of the thumb, passes through a pulley placed under the elbow, afterwards passing behind the back so as to end in a sort of bracelet surrounding the shoulder on the uninjured side of the body. The cord

Fig. 164.



being a little shorter than the arm is rendered tense as the arm is pushed away from the chest as a preparation to seize the object, the thumb is therefore placed in abduction. As soon as the object is placed between the thumb and index finger, the

arm is approximated to the body, and consequently the rubber spring forces the thumb against the index finger when the cord, *F*, is slackened. The apparatus of de Beaufort enables the maimed to hold a pen, pencil, or paper, but if the object is to seize hold of a certain weight, it slips because the spring which approximates the thumb to the fingers has not very much force. Were this spring too powerful, it would be an obstacle in the way of the draught cord, which would then only act very feebly at least as the maimed do not put the arm in a marked state of abduction, but in that position which is only in harmony with

Fig. 165.

Fig. 166.

the ordinary acts of life. Subsequent to the time of de Beaufort, Ange Duval had arranged the draught cord in such a way as to give it greater power. Duval's apparatus is shown in Figs. 165 and 166.

The apparatus consists of a wooden hand, made nearly the same as that of de Beaufort's, fixed to an anti-brachial sheath, which itself is fastened by two metallic splints (broken and articulated at the elbow) to an armlet enveloping the arm, which is maintained by two straight straps fixed around the shoulders. From the strap which passes over the healthy shoulder, starts (Fig. 166) a leather strap which supports a ring to which is attached the draught cord. In Duval's particular case the armlet supports a long stump sheath (Fig. 165), because this invalid had been so unfortunate as to have the left arm amputated, and the draught cord is attached to the cover of the same. In regard to the draught cord, *A*, which starts from the point, *D*, on the external surface of the thumb slips along the apparatus to where it meets the groove, *C*, and is afterwards reflected on the pulley, *B*, in order to reach its attachment by that on the stump cover or on a ring which has been placed on the upper portion of the opposite arm. The draught cord so arranged has much more power than that of de Beaufort's, because it is drawn by a double power represented by the separation of the shoulders; it is therefore possible to double the force of the spring, and consequently to carry objects of greater weight; the cord acts with still greater energy if it is passed behind the chest. It may be, it is true, an objection to this system, that the draught cord does not accommodate itself to the actual form of one in clothing; but it would be very easy to avoid this difficulty by surrounding the healthy arm with a small band, extending from its middle up to the axilla; and the cord reflected from the upper part of this band by a return pulley should be inserted into the lower part which still augments its power. The artificial limbs which we have described are the principal among those which have been proposed as a more or less perfect substitute for the normal forearm.

There exists certainly a great number of other models which we have not stopped to describe, because they do not represent particular principles. The choice to be made between all these artificial forearms may be determined in an absolute manner. It must all depend on the use which the maimed desires to make

of the artificial limb. If he wishes to employ it for actual labor, the laborer's artificial forearm of Mathieu, Charrière, and Gripouilleau have rendered the most valuable service. If, on the contrary, it is desired for light work, such as sewing, writing, etc., the artificial hand of Van Petersen, Charrière, de Beaufort, and A. Duval should be given the preference. The last two because of their greater simplicity should be accorded the praise, though it is proper to say, in the mean time, that they conceal less completely the deformity than those which have several movable fingers.

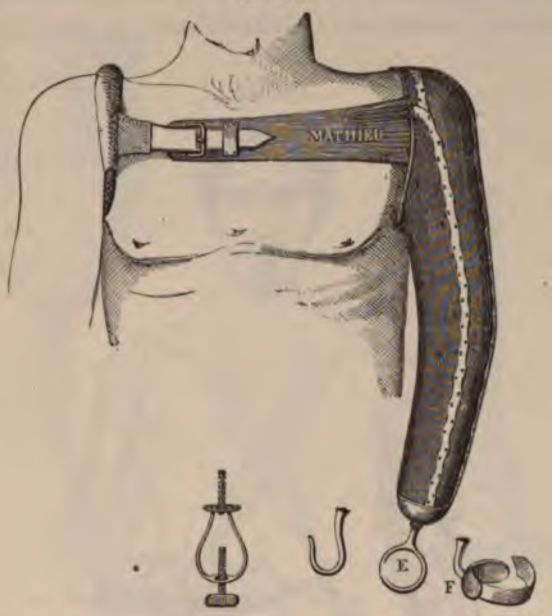
In cases where it is the principal object of the maimed to make such movements of the hand and fingers that the lookers-on may not imagine or even suspect the deformity, he will find decidedly the best apparatus in that which was designed by de Beaufort and carried into effect by Bechard. We ought to remark that the artificial arm, proposed after the accident to Roger, would accommodate itself to the amputations of the forearm after receiving some modifications.

Disarticulation at the Elbow and Amputation of the Arm.

We repeat here, as when speaking of the forearm, that the apparatus consists in a covering for the stump, to which cover we adapt hooks, rings, etc., and among the varieties are appliances for concealing the deformity, but movable only under the influence of the opposite hand, and also articulated mechanisms movable by means of springs and draught cords skilfully combined. The most simple apparatus consists of a leather sheath moulded and rigid, fixed with care around the arm, terminating inferiorly by a metallic or wooden disk, to which is attached a hook, destined to carry burdens, or to be employed in making traction. *The hook in some cases* may be advantageously replaced by the ring of Mathieu. *This ring serves* to hold the handle of a shovel or the shafts of the two-wheeled hand cart, etc. This apparatus, which is shown in Fig. 167, renders excellent service in any position where it is not rectilineal, but slightly curved inward, as it exists in the figure, in such a condition that it is a little

shorter than the opposite arm. If the stump cover was only bound around the arm, it would be liable to slip, and therefore it is necessary to fasten it on the shoulder and around the chest with leather straps, or, better still, to mould it accurately to the

Fig. 167.

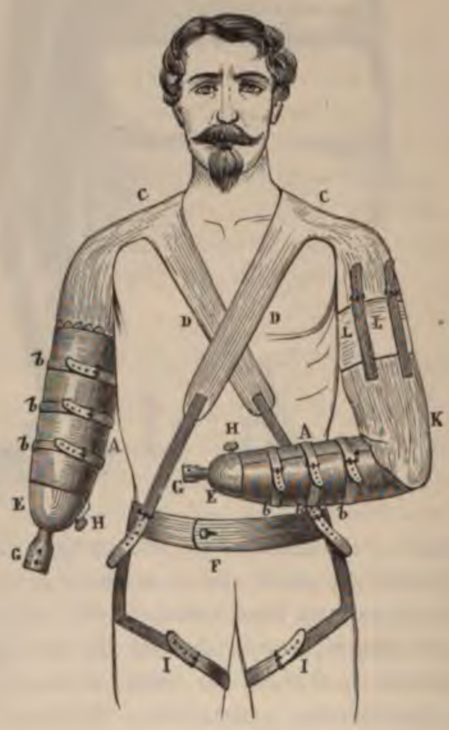


shoulders, where it is fastened by the strap which passes in front of and behind the chest, and is attached to the ring. Into the ring of the apparatus thus arranged, the maimed may slip the handle of a shovel, which, directed by the opposite hand, enables the laborer to perform the work required in the earth, to manage a wheelbarrow, a plow, etc. Mathieu has shown, at the exhibition of 1867, a man who was supplied with a covered stump, and labored with great facility. The handle of the instrument was held in the ring by the pressure which resulted from its inclination, as we have previously explained when speaking of the forearm. Some sorts of labor are more readily performed with the half metallic ring, *F*, completed by a leather

strap which permits the handle of the instrument to be tightened at will or with the vise screw.

Bonnet and Gripouilleau have designed within a few years a workingman's arm which may be very useful. The first knowledge of this apparatus was gained from a remarkable report made to the Academy of Medicine by Broca on the subject of the ingenious inventions of Gripouilleau. A complete descrip-

Fig. 168.



tion of this instrument is given in connection with the woodcut, Fig. 168, in which this apparatus is shown.

The arm of Gripouilleau is composed of a leather sheath, *A*, fastened by three leather straps, *b b b*, and joined to a shoulder piece,

C, made of very strong canvas and kept in its place by the stirrup, *D*, which passes down in front and behind the chest, and is fastened to the belt, *F*, the same being kept in position by the straps which pass around the thighs. The leather sheath ter-

Fig. 169.

Fig. 170.

minates inferiorily in a rounded piece of wood, *E*, in which plays the iron stem or armature. These last two pieces are exactly the same as those which we have already described as appropriate for the forearm. Only the cap does not articulate with the armature by a wooden joint. It is separated by an intermediate piece of iron, *D*, which represents the forearm, and articulates at *H* with the armature on which it may be extended and flexed

at will. (The above description will be better understood by examining Figs. 169 and 170. The former figure represents the articulation of the cap with the armature by the intermediation of an iron rod which represents the forearm. The latter figure represents the armature of the artificial arm.) The cap is fixed at the inferior part of this stem by an articulation, *G*, which permits it to turn on its own axis. Gripouilleau's arm acts in the same manner as the artificial forearm; the handle of the instrument seized by the cap finds a valuable point of support; accordingly it follows with the greatest facility all the movements of impulsion which it receives from the healthy hand; since the cap, performing the office of a hand, turns on itself, and since the stem, *D*, performing the functions of a forearm, flexes and extends according to the position of the opposite arm; *i. e.*, the arm directing the instrument, necessitates this flexion or extension. With this apparatus the amputation of an arm need not prevent the maimed from performing all sorts of farm labor by substituting other contrivances for the cap; such as the ring, etc.; or by adopting different instruments to these organs of prehension. Among these instruments, we especially mention the scythe, and an apparatus for cutting the branches of trees which are seized in notches of different sizes, *A A A*, shown in Fig. 171.

Fig. 171.

If the movements of rotation of the armature be useless they should be controlled by a key traversing the round pivot and the stem of the armature as has been previously explained; if the movements of flexion and extension be also useless they can be remedied by a key introduced into an orifice placed at the inferior portion of the armature and at the superior part of the stem, *D*. The principal part of the invention of Gripouilleau

resides in the stem, *D*, which represents the forearm; and the movements given by it, for the management of agricultural instruments, are truly very extraordinary. The apparatuses of Gripouilleau have never been too highly praised, not merely because they are so well arranged, but because they may be constructed by unskilled workmen at a trifling expense, and consequently in the most remote village the physician ought to be able to supply this contrivance. It is true the apparatus of the physician of Mount Louis is only suitable for farm labor and somewhat anolagous industries. It is nearly the same with all other artificial arms for laborers. The stiffness of the stump case (see Fig. 167) renders completely useless the adaptation of the knife, the fork, forceps, etc. In the mean time the artificial arm of Charrière escapes in part this inconvenience. Here the apparatus is flexible at the level of the articulation of the elbow, and may be studied in Fig. 172.

Fig. 172.

The sound hand places the artificial forearm at that degree of flexion most convenient for the accomplishment of the desired act; the stability of this degree of flexion is assured by the pressure of a button which acts on an internal spring. (This system is only a reproduction of that of Paré.) Consequently we are able to attach advantageously to the disk, which terminates the stump covering, a knife, fork, pincers, or an artificial hand. There may be also substituted for these instruments the hook or leather cylinder which we have previously described as being suitable for amputations of the forearm. The movements of flexion and extension may be executed by the metallic stem which supports the cylinder, and the stem is susceptible of semi-rotation which facilitates very much the management of agricultural instruments, a point which has been

already explained by us. The artificial hand conceals in some measure the deformity, but only renders real service in those conditions which were given while speaking of the forearm, although the movements are in some degree spontaneous. Van Petersen solved this problem by designing an apparatus where the ideas of Graefe are applied for the first time in an amputation of the arm.

Fig. 173.

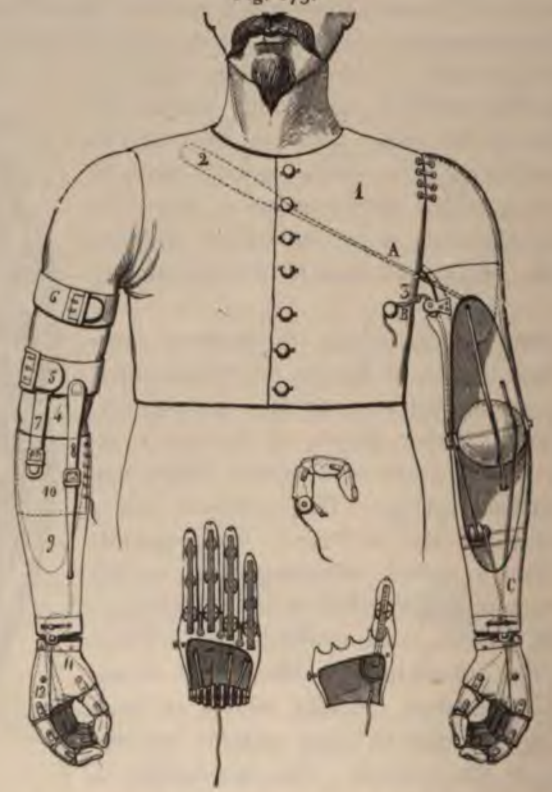
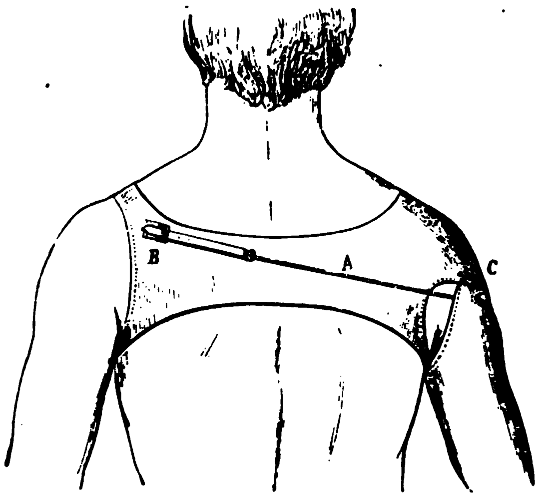


Fig. 173 represents the artificial arm of Van Petersen. It is incontestable that the invention of Van Petersen towers above everything done in the history of brachial prosthesis in our time. It is undeniable that we owe to the Dutch mechanic the

ingenious improvements which have rendered the artificial arm of our day so nearly perfect. Consequently we do not hesitate to make known this apparatus in all its important details, even to transcribe the report which Magendie made of it to the Academy of Science in 1844. The artificial arm of Van Petersen, said Magendie, is applied indifferently to all one-armed persons. Those who have only preserved intact the superior part of the humerus are apt to profit by it. The anatomy of the parts explains this necessity. At the scapular extremity there are several muscles inserted into the bone, which starting from the back, and from the various parts of the shoulder, are the principal agents in the numerous movements of the arm. The stump still executes all these movements when the origin and insertion of these various muscles remain undisturbed; it is carried away from the body; it is approximated to the body; it is carried in front and behind with the greatest amount of energy when the stump is sufficiently long. M. Van Petersen has thought that part of these movements should be retained, or as much as possible of the muscular force which produces the same, and it is on this basis that he has founded his invention. The artificial arm is formed of these articulated parts, which represent the arm, forearm, and hand. The hand is composed in a like manner of the carpus and fingers, the latter having the movable phalanges maintained in a persistent state of flexion and in contact with the thumb by the springs. The whole weight of the hand is scarcely 500 grammes. The stump is received in an excavation in the apparatus, and is firmly fixed there by a corset, of that sort which readily transmits to the artificial arm all the movements which are made by the stump, *i. e.*, if he brings it forward, backward, upward, or downward. But this is only the most easy; we have often seen persons with an arm, attach to the stump cover a stick or a hook, and use it with much dexterity. The real difficulty was to produce harmonious action between the different pieces of the apparatus; in other words, to cause the movements of the forearm to produce the proper responses of the arm, the hand on the forearm, and the fingers on the hand. This is a complicated result, but it is necessary in

the production of some of the required movements of the arm and hand. M. Van Petersen has obtained it by a procedure which may now be studied in Fig. 174.

Fig. 174.



It should be first observed that a corset is applied to the chest, and to this corset are attached catgut cords, *A B C*, which are fastened as follows : 'one to the forearm and the others to the fingers. When the maimed brings his stump forward it produces a traction on the forearm which flexes the arm. When, on the contrary, the stump is carried backward, the forearm is extended and the arm is thrown out from the body at will. The movements of the fingers, indispensable for the seizure of objects, are produced by a similar and not less ingenious mechanism. A cord, *A*, is fastened by one extremity to the corset, while the other extremity is attached on the dorsal surface of the flexed fingers. When the stump is carried away from the body, it draws on a second cord, *B*, overcomes the resistance of the spring, extends the fingers, and opens the hand. In order to seize an object the maimed has only to conduct his open hand to the handle of the object, when he draws

the stump gently inward toward the chest. Then the spring flexes anew the fingers, the hand closes, the object is seized as firmly as possible, since each of the fingers acts independently of the others and press separately on the part which it touches. The object having been seized requires no more attention from the maimed, it being now a matter for the springs. To bring the hand to the mouth he brings the stump forward, the forearm is flexed, and the hand is brought to its destination. To release an object and to place it on the table for example, it is necessary to carry the stump backward, which extends the forearm, and then to carry the stump outward from the body which produces extension of the fingers and the abandonment of the object. It is without doubt necessary for the maimed to practise before he can apply this apparatus skilfully and with promptness; but it has generally been done with so much dexterity as to favorably impress our commissioners. Such is the artificial arm of Van Petersen, light, solid, simple in its mechanism, fulfilling the intentions of its inventor, and proving very useful to persons who have had the misfortune to lose one arm or even both. The report on the employment of this apparatus is even free from vanity when Magendie says, clothed with the sleeve of his dress and neatly gloved, the arm of Van Petersen produces a complete deception, and especially if the maimed employs it with a certain promptness.

Magendie concludes by citing some examples. An invalid who had lost both arms in the war of the first empire, and who by the aid of two artificial substitutes, took with the right hand a full glass, carried it to his mouth, then emptied it, and afterward returned it to the table from which he had taken it. We have seen the same invalid, added Magendie, pick up a pin, seize a sheet of paper, etc. The utility of the arm of Van Petersen has therefore been demonstrated by experience, but nevertheless in later years attempts have been made to perfect it by rendering easier the movements of the forearm on the arm, the wrist on the forearm, and especially to give the forearm the movements of pronation and supination. The senior Charrière made an effort in this direction. The artificial arm of Charrière

is shown as a whole and in its various parts in Figs. 175, 176, 177, and 178.

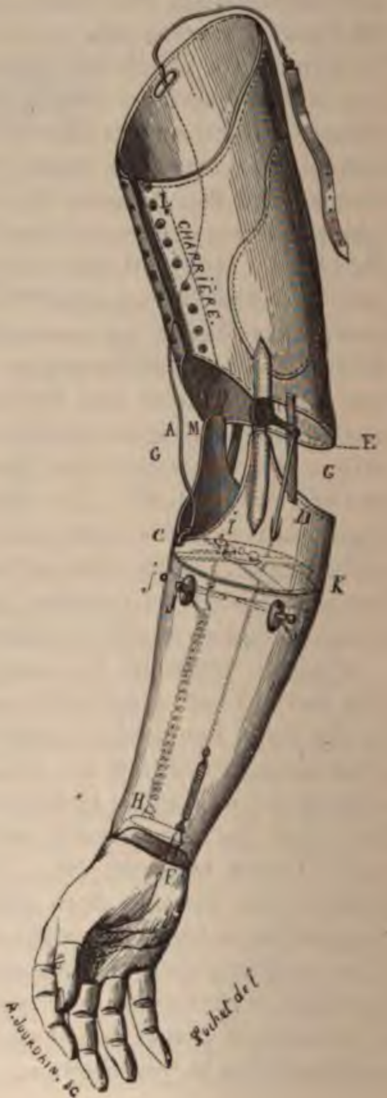
Fig. 175 represents the mechanism adapted to the articulation

Fig. 175.

Fig. 176.

Fig. 177.

Fig. 178.



at the elbow to determine the pronation and supination; Fig. 176 shows the upper part of the forearm; Fig. 177 the forearm; and Fig. 178 the whole apparatus, which is composed of an armlet laced at *L*, and attached by a buckle to a strap surrounding both shoulders, the same as in the system of Van Petersen. The sheath is fastened by two metallic straps to a forearm of prepared leather, two novel hinges uniting the latter to a light wooden hand. The phalanges of the fingers are united firmly enough in their articulations to remain in any position that it may be convenient to give them. A catgut cord, *A*, attached to the forearm at the point, *C*, runs along the armlet, passing under a pulley, and returns to be attached to the strap which surrounds the healthly shoulder. The elevation of the stump determines the tension of the cord and consequently the flexion of the forearm. The flexion of the forearm determines the tension of the second cord, *D*, and this cord fixed at *E* at a point eccentric to the articulation of the elbow, terminates inferiorly in a strong spring fixed to it at the point, *F*, on the base of the hand. The elevation of the stump produces consequently a double movement; first, the flexion of the forearm; second, the flexion of the wrist. When the stump is lowered the cord ceases to be tense, the forearm falls again under the influence of its weight and the two elastics, *G G*, placed behind the elbow. A spiral spring fixed at the point, *H*, on the outer side of the hand, and at the point, *I*, on the forearm determines the straightening of the hand. In order to render the deception more complete, it is necessary to give the forearm the movements of rotation. This has been obtained by forming the forearm in two parts, the one superior the other inferior, the latter part, being represented in Fig. 178, is arranged in a style to enable it to turn on the superior by means of a light impression given to the projecting button, *J*. This impulse is given by the sound hand; but if the subject is adroit he may bring the artificial forearm in contact with the hip which will act on the button, *J*, by an imperceptible movement.

We have remarked that in the arm of Charrière the movements of rotation of the forearm and the flexion of the fingers

26

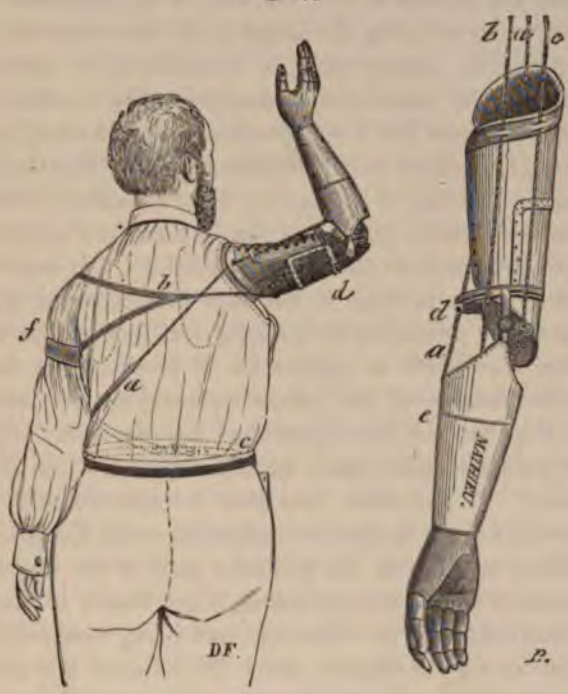
are confined to the hand of the opposite side. This meets the indications of the special cases for which it was designed, acting very simply with the power of the lever, in certain directions, by the touch of the hand; in a word, with the production of scenic effects.

Charrière's son has pushed still further the perfection of this apparatus which we are describing, by designing a system permitting the introduction of a double spontaneous movement of pronation and supination, and likewise the flexion of the fingers. This system is represented in Figs. 175 and 176, and is described in the author's own language as follows: "The wheel, *M*, by the addition of the cog-wheel, *N*, makes one entire turn with the complete flexion of the forearm. In accordance with this we observe that, *first*, for the flexion, this eccentric wheel makes a half turn, draws on the cord, *O*, which rolls itself on the pully, *P* (Fig. 176), at its point of attachment, *R*, on the cross of the lower part of the forearm, where the hand is fixed, and which, pulling this, produces the movement of supination with the least possible degree of flexion of the forearm; *second*, if one should flex the forearm completely, the eccentric wheel will continue to turn, and will descend to its first position; then the cord lengthens itself, the spiral springs, at which the point of attachment is *T*, which should, at the traction of the first movements, shorten and bring back the hand into the first position by the movement of pronation. The same movements of the hand are produced when the forearm is extended. The flexion of the fingers may be produced by the aid of this system."

One of our most able manufacturers, Mathieu, has made in his turn an apparatus destined to perform the same movements as that of Charrière. The problems which Mathieu attempted to solve were the following: *first*, to give motion to all the fingers in every direction, and the same to the wrist and forearm; *second*, to permit the forearm to be flexed on the arm to enable the maimed to apply it to the chest, to extend it, to raise it above the head and to place it behind the same, and to put it also behind his back. Mathieu has solved these difficulties as well as it could be desired with the apparatus shown in Fig. 179.

The armlet which surrounds the humerus is composed of two parts united together by the two concentric metallic circles, indicated by *d*, the external circle, which belongs to the inferior part of the armlet, rolls on the internal circle which belongs to

Fig. 179.



the superior; this movement of rotation is never known to exceed the one-third part of the circle, because it is limited by three buttons which are raised from the internal circle, and penetrate three slots made in the external circle. The anti-brachial portion is also divided into two parts by a cut made at the point *e*; the inferior part may be made to roll on the superior part. The hand is made of linden wood, the fingers are articulated and maintained semi-flexed by the springs, but they are susceptible of movements of extension. An examination shows, indeed, that the different parts should move the one

on the other. The elbow is flexed by means of the cord, *a*, which, after having lengthened the arm, passes behind the back that it may be fastened to one of the buttons on the waistband of the pantaloons. If the invalid carries the arm away from the chest, he increases the tension of this cord, and consequently determines the flexion of the forearm; if he increases the size of the thorax by inflating the lungs, it still increases the tension of the cord, and, consequently, it determines the same effect. The movement of supination is determined by another cord, *e*, which, starting from the lower portion of the forearm, proceeds to the band, *f*, attached to the healthy shoulder; this cord, led by an analogous movement to that we have indicated for the cord *a*, acts on the inferior portion of the forearm, and compels it to execute a movement on the superior portion; this movement is that of supination, because in the state of repose the apparatus is maintained in pronation by a spring arranged within the forearm. The movement of supination is produced at the same time as the flexion of the elbow by carrying the arm away from the side, and the development of the shoulder; the extension and pronation take place, on the contrary, when all efforts have ceased. At the same time that the movement of supination is produced, the fingers are extended under the influence of a cord which starts from the posterior part of the forearm (this cord concealed within the apparatus, is not shown in the figure), divides inferiorly into five branches, one being destined for each finger and one for the thumb; when the forearm is in pronation, it is not stretched, and, consequently, it permits the springs to act which maintain the fingers flexed; when, on the contrary, the arm is moved to place it in supination, the cord is twisted around the imaginary axis of the forearm, and by this movement it extends and forces the fingers to open in the same manner as they are completely extended at the end of the movement of supination. To complete the illusion Mathieu has succeeded in making the extension of the index finger independent of the other fingers, by means of the last draught cord, *b*, which starts from the index finger, presses along the arm, surrounds the healthy shoulder, and is finally fastened to the

waistband of the pantaloons. The working of this apparatus should only be regarded as perfect when the maimed is able to carry the artificial arm forward, backward, upward, or downward, all in executing the movements which we have described. This object is attained by dividing the brachial sheath into two parts; by throwing the stump slightly outward, etc.; thus the maimed makes the external circle turn on the internal in the same direction, and *vice versa*, all the lower part of the apparatus following the movement of the external circle. It is this rotation of the inferior part of the apparatus on the superior which enables it to combine with the simultaneous movements of pronation, supination, flexion, and extension of the fingers, which constitutes the true originality of Mathieu's artificial arm.

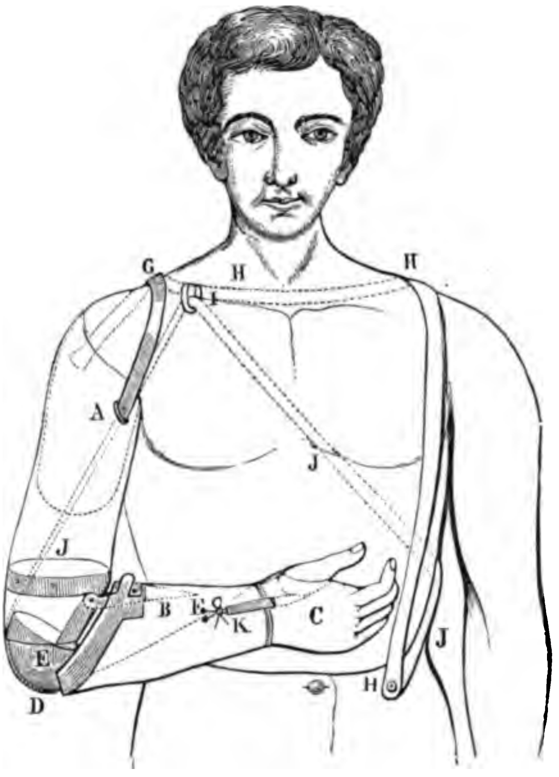
The senior Bechard has also designed a very ingenious artificial arm, possessing not only the movements of flexion and extension, but likewise pronation and supination. In this apparatus the piece which represents the forearm is divided into two parts; the superior is united by two splints to the band which surrounds the humerus, and the inferior one is articulated with the hand. The inferior part representing two-thirds the length of the forearm, carries, at its superior part, a movable turntable, which turns ón the superior piece by the aid of bone rollers sliding over a circular iron surface; in this manner, the forearm and the hand may describe a movement of rotation equal to the one-fourth of a circle. Where no other force controls the action of the forearm it is maintained in pronation by a spiral spring fastened to the centre of the turntable. The movement of supination is produced by a catgut cord, which, starting from the top of the movable piece, where it is in communication with the turntable, ascends the length of the amputated limb, passes behind the shoulder, and then obliquely downward until it reaches the waistband of the pantaloons, and from this point it again descends obliquely to the opposite hip. It is sufficient to bring the arm into a state of abduction, for as soon as the cord, in extending, causes the turntable to move, it will produce the movement of supination. The movement of supination leads to the extension of the fingers which are maintained in a state of

flexion by the springs, when the arm is at repose, that is to say, in pronation. The extension of the fingers is determined by the elevation of a metallic stem which is surrounded by an endless screw, bearing a nut which is elevated during supination and lowered during pronation; this nut itself terminates with two iron stems which are attached to the extensors of the fingers. The movement of abduction of the amputated arm suffices therefore to determine at the same time the rotation of the arm, which places it in supination and the extension of the fingers, but this double movement, sufficing when it pertains to an amputation of the forearm, should be combined with flexion at the elbow, where this is disarticulated, or, still more, when the arm is amputated. The desired result may be obtained by employing a second draught cord, which is attached to the superior and inner side of the artificial forearm, extending up as far as the shoulder on the side of the amputation, from which it passes transversely over to the opposite shoulder, and is finally attached to a ring surrounding the upper part of the healthy arm. It is sufficient to bring it into a state of abduction, that the cord should be rendered tense in flexing the forearm on the arm. It will now be observed, that in order to bend the elbow, put the arm in supination, and extend the fingers, the maimed has only to bring both arms into a slight abduction. We here remark that in the artificial arm of Bechard, an ingenious mechanism permits the hand to be changed at will which terminates the apparatus. The fingers are not maintained in flexion by spiral springs, as in the majority of the other artificial hands, nor prompted to extension by catgut cords. A simple metallic spring is placed within the apparatus and arranged in a state of flexion, so that by drawing on the upper part produces extension and the opposite movement when the action ceases. The thumb is only moved by the aid of two discharge pulleys, attached to the general motive power in such a manner that, when the fingers are in extension, it executes the same movement; still better, it is led in the abduction to become flexed again and in the adduction to repose.

These modifications have been suggested to Bechard by de Beaufort, who has likewise given the advice to place in its

proper position the metacarpo-phalangeal articulation; it is generally known that the first phalanx in the artificial hand has only two-thirds of its normal length. The artificial arms of Charrière, Mathieu, and Bechard, are luxurious instruments, and fulfil only a single indication, ***permitting the maimed to make all the gestures which he could execute with a natural arm.*** But there is nothing more to be demanded of them, they are not able to render valuable service in the performance of the ordinary duties of life. The possessor cannot even hold with them

Fig. 180.



a knife, fork, pencil, paper, etc. In this respect they are inferior to the arm of Van Petersen. De Beaufort, stimulated by the

efforts of Van Petersen, has constructed a very simple and useful apparatus for the performance of light work. De Beaufort's instrument, which is shown in Fig. 180, is composed of two leather sheaths, *A* and *B*, embracing the arm and forearm, which are united together at the elbow with light wood, articulated by the hinge, *E*, permitting flexion and extension of the forearm in different degrees. The stability of the hinge in a chosen position is assured to the maimed by a catch formed of a piece of hard wood, which slides from the arm to the forearm, or is adjusted by a peg, *F*, with which it is pinned. It is internal when employed in a case of amputation of the arm, and external when it is employed in a disarticulation at the elbow. The hand which terminates the anti-brachial sheath is exactly similar to that we have described when speaking of the amputation of the forearm; it is, therefore, formed in a single piece, *C*, on which moves a wooden thumb approximated to the fingers by a rubber spring, *K*. A draught cord, *J J*, assures the separation of the thumb. Before studying the action of this cord, it is convenient to speak of the manner in which the apparatus is attached to the stump; a stirrup in double leather, *G*, attached to the superior part of the ring, *A*, surrounds the shoulder on the side of the amputation; and is adjusted by a leather strap, *H H H*, which slips behind the chest to surround the healthy shoulder and to be attached below to the buttons on the waistband of the pantaloons. This leather strap supports at *I* a pulley on which there is applied a draught cord, *J*, which starts from the external side of the thumb to pass behind the apparatus and the trunk in such a manner as to be attached to the waistband of the pantaloons. It may be readily seen that the least elevation of the stump tightens the cord, consequently determines the separation of the thumb from the fingers, and, therefore, when the maimed wishes to seize an object, he has only to advance the stump toward it, so that the grasp represented by the thumb and fingers shall be opened; as soon as the object is within this grasp, he approximates the stump to the chest, and immediately the cord is rendered tense, the spring, *K*, acts, and the grasp is closed. It is easily comprehended that the maimed who is supplied with this

apparatus is able to hold a hat, a pencil, pamphlet, etc., but he is only able to seize light objects for reasons which we have mentioned while speaking of the artificial forearm. Here still we advise the draught cord to be attached to the opposite arm in order to increase the force of the rubber spring. In the preceding system, the forearm is only movable on the arm by the assistance of the opposite hand.

De Beaufort has designed an automatic system of extreme simplicity for the purpose of determining flexion and extension at the elbow. This apparatus bears a resemblance to that which we have already described, since only the catch at the articulation of the elbow is abolished, while the mechanism now consists of a hinge permitting flexion and extension. One or two rubber springs descend from the lower part of the brachial sheath to the lower part of the anti-brachial. These springs acting eccentrically are arranged in such a manner that, when the arm falls to the side of the body, its force is exactly counter-balanced by the weight of the hand. If, on the contrary, the arm is raised, the weight of the artificial hand becomes horizontal, and ceases to act on the spring; this, being restored to power, leads necessarily to the flexion of the forearm on the arm. This mechanism, which is remarkable for its simplicity, is truly admirable, it removes from the apparatus the ordinary stiffness which always betrays the presence of an artificial organ; in the mean time it is perhaps less useful than the arm with a fixed articulation at the elbow, because it does not permit the handling of as weighty objects. It is very easy to unite, in a single apparatus, the advantages of both of de Beaufort's systems, by arranging the articulation at the elbow in such a manner that the latch may be put in place or removed at will. De Beaufort's artificial automatic arm might be adapted to the artificial hand which he designed for use in cases of amputation of the forearm. The apparatus would then become a luxurious arm. We would observe here that the apparatus which we have figured (Fig. 162) represents an automatic arm; the letters *O O* indicate the two rubber springs. It is truly very difficult to make a choice between all the artificial limbs which we have examined and

reported on. We repeat here what we have said on the subject of amputations of the forearm: the best apparatus is that which fulfils in the best manner the requirements of each particular case, and these should be determined by the desires of the invalid. It is on the last evidence that the complicated arm of Mathieu, Charrière, and Bechard are designated as instruments of luxury, convenient for men who are required to speak in public and make gestures, but they render no other service, not even holding a pencil firmly enough to permit writing.

We have said quite as much of the automatic apparatus of de Beaufort, when he puts in motion a complicated forearm like that which we have already described. We have not at any time even tried to decide which is the best of these artificial arms, because some of these can only be conveniently managed by marvellously adroit men, although to a man capable of rendering service as an artist on a musical instrument, there should perhaps be supplied the artificial arm of Mathieu to whom it will be found most serviceable; nevertheless, in the hands of a man less gifted the less complicated arm of Charrière and Bechard acts more regularly. It is then an individual question without any general application.

The apparatus of Van Petersen, which has only the movements of flexion and extension at the elbow, wrist, and fingers, conceals less perfectly the deformity than the others which have just been mentioned, but in return possesses greater power of prehension, and is consequently more serviceable. The arm of de Beaufort, which conceals the deformity less, terminates in a hand with a sort of grasp, which enables the maimed to seize light objects more firmly, and is consequently the most useful arm for the man who requires it for manual labor. But if it is not necessary to conceal the deformity, all these artificial arms are worthless, and the man who requires an arm for the performance of real manual labor will find nothing which can be substituted for the covered stump terminating in the concavo-convex piece of wood of Charrière, the rings of Mathieu, and the different pieces of Gripouilleau.

Disarticulation at the Shoulder.

The means of prosthesis most frequently employed in cases of disarticulation at the shoulder consists of an artificial arm in which the armlet is enlarged, adapting it to larger surfaces, including the superior part of the shoulder and even the anterior and posterior regions of the trunk. Almost always these artificial arms are wanting in usefulness, but they serve to render the

Fig. 181.

Fig. 182.

Fig. 183.

mutilation less evident. Very recently, and at the same time, Robert and Collin have constructed two very ingenious and useful artificial arms, one being intended for light work, such as carrying a letter, paper, etc., and the other for heavy work.

The apparatus intended to be used in light work is represented in Figs. 181, 182, and 183.

Fig. 181 represents the nature of the deformity; Fig. 182 the corset and cover of the stump, anterior view; while Fig. 183 shows the general appearance of the apparatus. This apparatus was constructed for a young man who had submitted to a disarticulation of the left shoulder and an amputation through the upper part of the right arm. The apparatus for the disarticulation was composed of a canvas jacket, *A*, buckled in front and separated behind into two parts which were united by an elastic band, *B*. To the corset is sewed a stump cover (Fig. 182), enveloping accurately the shoulder, and fastened to an artificial arm. This artificial arm, composed of an armlet, *G* (Fig. 183), an anti-brachial sheath, *H*, and an articulated hand presents nothing which we have not studied in the preceding article; and consequently we shall limit ourselves to describing its articulation with the shoulder and the means which are employed to put it in motion. The articulation is formed by means of a metal plate in the form of a *T*, firmly fixed at *D* to the stump cover; the two small branches of the *T* are thrown transversely over the shoulder, the large branch descends towards the armlet, *G*, and articulates at *E*, by a button, with the metallic stem, *F*, which occupies the external lateral part of the armlet; with regard to the movements, they are determined by the draught cords, *K K K*, which starting from the anterior and external side of a strap, *I*, surrounding the base of the corresponding thigh ascend upward along the sides of the body, and come by describing a light curve to the pulleys, *M M*, on which they are reflected. Below these pulleys, the cord, *K*, descends to the pulley, *M*, over which it passes, in order to penetrate the interior of the armlet at the level of the articulation of the elbow; it is also reflected on the last pulley, *M*, in order to be inserted at *O* into the superior and posterior part of the fore-arm. The slightest elevation of the shoulder results in tightening the draught cord, and consequently the flexion of the fore-arm on the arm; the articulation of the shoulder participates

but slightly in this movement, but even that was useless for the attainment of the object indicated.

In reference to the movements of the hand, which are not spontaneous, the fingers are maintained in a state of flexion by the springs which assure the solidity of prehension, when the object has been placed between them. The hand employed with this apparatus is that which was designed by Charrière. Nothing is easier than to substitute for this hand one with a movable thumb, like that of de Beaufort's; it is sufficient to add a second draught cord having an arrangement similar to the first. It was formerly thought that the movements of the thighs in walking would have the effect of making tense the draught cord, *K*, which would give an ungainly movement to the forearm. We have assured ourselves that these movements relax the cord and consequently have no other influence. The artificial arm of the right side, represented in Fig. 183, is moved by a system which we will now describe, as the movements are more perfect, since the normal articulation of the shoulder is preserved. We ought to remark that in order to supply greater length to the stump, *i. e.*, to increase the length of the lever of the arm, Robert and Collin have had recourse to an artificial stump, a contrivance which we describe with considerable detail as being suitable to amputation of the leg. The second apparatus, which is intended for laborers, and which is somewhat similar to that which we have just described, is represented in Figs. 184 and 185.

Fig. 184 shows the general appearance of the apparatus, while Fig. 185 represents the internal mechanism. This apparatus is composed of a moulded leather sheath enveloping accurately the stump of the shoulder, the anterior and posterior part of the chest, while the covered stump is fastened by a large cushioned leather strap, *B*, which starts from the posterior part of the thorax and passes downward to the healthy axilla and is buckled in front; a more slender strap, *C*, extends from the strap, *B*, to the most elevated part of the covered stump in order to prevent the rocking movement of the arm. The artificial arm is composed of a brachial armlet, the forearm, and the convex piece of wood which we have already described. The

armlet may be distinct from the covered stump, but should be joined to it by a mechanism very similar to that of the preceding apparatus. A piece of metal in the form of T, is placed on the shoulder at D, the large branch of the T is articulated

Fig. 184

Fig. 185.

at E, at the normal level of the scapulo-humeral articulation, with a very strong piece of metal which descends on the interior of the armlet and is articulated, at the level of the articulation of the elbow, at F, with a second metallic stem, which, occupying the cavity, terminates at H by a bulbous enlargement crowned by a screw to which there is attached a leather cylinder. In fact, it is these metal stems which constitute the artificial arm; brachial and anti-brachial armlets are only, so to speak, adjuvants and ornaments. At the lower part of the brachial armlet is fixed a convex piece of wood serving as a point of support for the anti-brachial armlet in its different movements of flexion and

extension. The forearm is flexed on the arm by aid of the hand of the opposite side, a small semicircular metallic plate pierced with holes (Fig. 185) is attached to the anti-brachial stem, and slides on a similar plate, also pierced with holes, and dependent from the brachial stem; a pressure screw, *G* (Fig. 185), which we see at the sides of the elbow (Fig. 184), penetrates these holes and insures immobility in the degree of flexion desired by the maimed for different sorts of labor.

Let us examine the character of this apparatus; let us suppose the handle of a shovel, broom, or any other instrument placed in the leather cylinder and guided by the uninjured hand; the artificial arm advances and recedes as far and at the same time as the arm of the opposite side, since it is susceptible of movements forward and backward, at the level of the articulation of the shoulder; at another point, the stem of the leather cylinder may describe semi-movements of rotation, to the right or left by the action of the screw. It is easily understood that the maimed furnished with this apparatus is enabled to take part in certain kinds of labor. The maimed to whom this apparatus has been supplied begin immediately to sweep even without previous practice. If we wish to give to the shoulder-joint more extensive movements we should substitute for the hinge articulation, *E*, a ball-and-socket joint *J* (Fig. 185). We should now remark that the movements of the arm on the shoulder should not fatigue the stump because it is protected by the stump cover and will not bear any friction.

Measurements Required for the Manufacture of Artificial Arms.

We believe it useful to enter into some of the details of this subject, because the measurements being well done and the fittings properly made will sometimes enable the maimed to avoid serious displacements. It is very important to take a mould of the healthy arm and likewise of the stump. These moulds are indispensable when the prosthesis relates to an amputation of the hand or wrist; but their places may be supplied

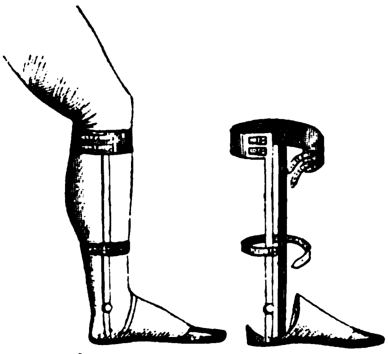
by the aid of metric measures in amputations of the arm, elbow, and forearm. These measures are the following according to Charrière. 1. Total length from the tip of the fingers to the shoulder; 2. Length from the elbow to the shoulder; 3. Length from the elbow to the axilla; 4. Length from the wrist to the elbow; 5. Length from the base of the fingers to the wrist; 6. Length of the middle finger; 7. Size of the hand at the base of the fingers; 8. Circumference of all the fingers; 9. Circumference of the wrist; 10. Circumference of the forearm below the elbow; 11. Circumference of the forearm over the elbow; 12. Circumference of the arm below the axilla; 13. Transverse diameter at the elbow; 14. Length of the stump to start from the articulation above it; 15. Circumference of the stump; 16. Indicate the interval from one axilla to the other. To be properly understood, it is necessary to say whether the limb is to be employed on the right or left side. In the case of an amputation of the shoulder it is indispensable to add to the preceding a perfect cast of the same.

Prosthesis of the Lower Extremities. Partial Amputation of the Foot.

After the amputation of the toes a slipper conveniently stuffed at its anterior extremity generally suffices to fulfil all the indications; it is also sometimes sufficient when the bones of the tarsus have been removed. However, the disappearance of the fore part of the foot more frequently necessitates the employment of a special apparatus. The simplest and best consists of a metal sole endowed with resistance as well as a certain degree of elasticity, especially in its anterior part, while its posterior part permits a raised border to fit around the heel. Two metallic splints, light and at the same time firm, starting from the sole of the slipper to ascend along the leg to which they are fastened by two well-cushioned leather straps, these splints ought to be articulated at the level of the tibio-tarsal joint. A portion of hollow wood, representing the anterior part of the foot, is fastened to the sole; and it ought to be arranged in such

a way that the anterior and upper parts of the stump receive no pressure capable of irritating the cicatrix. This apparatus, ordinarily covered with a sock, is represented in Fig. 186.

Fig. 186.



When the surgeon is compelled to remove the first and second metatarsal bones, the internal border of the foot inclines inward, whilst the external border is raised, these deviations being frequently accompanied by an inclination of the anterior portion of the foot outward. Here the results of prosthesis become infinitely varied, and we have not described them because they are based on the principles which pertain to orthopædia. We have made the same observations in regard to the deviations which result from the removal of the fourth and fifth metatarsal bones. Legouest has remarked that these deviations are nearly identical with those which follow the removal of the first metatarsal bone. If the prosthesis is simple in the preceding cases, it meets with considerable difficulty when the amputation has been performed in the medio-tarsal articulation, *i. e.*, between the astragalus and calcaneum on the one part, and the scaphoid and the cuboid on the other. In consequence of the tarso-metatarsal amputation, the foot, continuing to rest on the sole in the whole of the resisting parts of the plantar surfaces, furnishes a very firm base of support; but as a result of Chopart's operation, on the contrary, the heel is nearly always raised in such a way that the maimed

does not walk on the plantar surface of the foot, but on the stump itself.

This situation is unfortunate and frequently unavoidable because the stump is not slow to become very painful. In the mean time there are a few exceptional cases which present themselves among these subjects with a flat foot in whom the heel is not raised and the weight of the body rests directly on the inferior face of the calcaneum; here the prosthesis is as simple as after a Lisfranc's amputation, and the deformity is remedied by the same means and apparatus. But if the heel is raised this apparatus is not applicable and it is evident that it can be remedied only imperfectly by any other means, since it would be the stump and not the plantar surface of the foot which would be brought in contact with the metal sole of the boot. The effort has been made to counteract the drawing up of the heel by section of the tendo Achillis, but this operation has had no beneficial result; and it should be so, for the tendo Achillis only plays a secondary role in this deformity of the stump; the real cause consists in a dropping of the anterior part of the calcaneum, a result provoked by the destruction of the antero-posterior arch of the foot; it suffices, to convince yourself of this fact, to cast your eye on the skeleton of the foot and leg. If this deformation does not arise among the subjects with flat feet, it is certainly because it does not exist among them in the antero-posterior arch. It is therefore necessary that the prosthesis correct this difficulty. Ferd. Martin has accomplished this object, by avoiding all attempts to make the maimed walk on the amputated parts. The apparatus of Martin, which is shown in Fig. 187, is composed of a leather sheath, moulded on the stump, and embracing the surface accurately,

Fig. 187.

two metallic splints, the one being situated on the inner side, the other on the outer side, are sewed to the sheath. At the lower part, these splints articulate with a metal stirrup, fastened to a slipper of the same metal; the anterior part of which is occupied by a piece of cork, which is shaped so as to resemble the natural foot. A rubber band crosses the dorsum of the foot and maintains the artificial foot in a state of flexion when the weight of the body does not rest on the slipper. This apparatus is well combined; all direct contacts with the stump are avoided, and moreover the leather sheath preventing the slipping of the osseous surface, prevents the increase of the deformity. It has been applied several times with complete

Fig. 188.

Fig. 189.

success, although it failed completely in the case of a rich merchant of Rheims which Debout has made known to history. After having expended in ten years about thirty thousand francs, without any material benefit, this merchant then applied to Bechard senior, for an artificial limb, and this ingenious me-

chanic succeeded in making his patient walk by slightly modifying the apparatus of Martin. This apparatus as modified by Bechard is shown in Figs. 188 and 189.

Bechard's modification was brought to bear on two points: 1. The stirrup was attached to the leather which forms the upper part of the shoe which was supplied with a metallic sole; the apparatus in this way becomes less heavy than the primitive instrument of Martin, which should be concealed in an ordinary shoe; 2. Bechard has placed a tendon in front and another behind the leg to facilitate the movements of flexion and extension of the foot. The lesson taught by the case of the merchant, which is far from being an exception, demonstrates the difficulties which may be met whilst endeavoring to cause to walk those who have suffered an amputation at the medio-tarsal articulation. Surgeons now endeavor to obtain better results by preserving large plantar flaps, and especially by guarding carefully the tendons of the dorsal surfaces of the foot; they hope that these tendons may unite themselves to those of the plantar flap, thus forming a sort of hammock in which may rest the calcaneum and astragalus. The possibility of this union is not doubted, but it does not certainly suffice for the reason that to prèvent the calcaneum from inclining forward, it is necessary to contend against an enormous force represented by the entire weight of the body. It is necessary to be able to fold up the inferior flap under the anterior part of the calcaneum, which finds in this obstacle a point of support sufficient to prevent it from rocking; unfortunately, this conception is almost impossible of realization. The surgeon has neither the power to prevent the deformity of the stump, nor to correct it when it exists. The prosthesis is barely able, in some cases, to palliate it with extreme difficulty. It seems that Chopart's operation should be renounced, and that there should be substituted for it in principle the tibio tarsal or, *perhaps*, subastragaloid amputation.

Tibio-Tarsal Amputation.

The prosthesis of this amputation is simple, especially if the operation has been performed according to the method of Jules

Roux, who preserves a large plantar flap admirably arranged for the support of the weight of the body. Baudens, who has performed this operation, employs as a means of prosthesis a sole furnished with an elevated heel—with a bed of cork, and an elastic cushion—for the purpose of remedying the shortening of the limb. A thick leather boot leg, attached to a shoe, ascends along the leg embracing accurately the stump; two lateral metallic splints descend along the leather case and are

Fig. 190.

doubled under the shoe in the form of a stirrup, in order to insure the inflexibility of the whole apparatus. This shoe of Baudens is much too heavy; if the wish is to mask the deformity, recourse should be had to the boots which we shall describe as proper for the submalleolar amputation; but these

elegant boots are less serviceable than the peg-leg shoe of Jules Roux. This peg leg is shown in Fig. 190.

This apparatus is composed of a simple heel united very firmly to a leather boot leg which is laced in front of the limb. The heel is composed of a thick bed of cork which is covered with chamois skin on the inner side. The truly essential thing, said Jules Roux, is the unyielding inflexibility of the leather which embraces the stump and leg. The absence of this resistance invariably causes a sort of crack in the boot, and the maimed would walk with uncertainty, since the apparatus inclines or yields at every step at the point of this break. If the leather was not sufficiently strong, as happened, for example, to M. Reynaud, Inspector-General of Marine Service, there should be placed on either side a lateral metallic splint. We ought to remark that the boot of Jules Roux does not possess any of the springs intended to facilitate locomotion; these springs are useless because the muscles of the anterior and posterior regions of the leg preserve all of their energy, thanks to the precaution taken by this eminent surgeon, while the explanation of its success is as follows: In the first instance, the tendo Achillis is not cut, but simply detached from its osseous insertions in order that the rest of it may remain attached to the plantar aponeurosis; while, on the other hand, the anterior tendons are preserved of sufficient length to enable them to be lodged on the extremity of the bone or in the cicatrix. The apparatus which is adapted to tibio-tarsal amputations is perfectly applicable in the subastragaloid disarticulations.

Amputation of the Leg.

The most simple means employed in the case of those persons who have submitted to an amputation of the leg consists in the employment of the classic peg leg. The peg leg without doubt possesses the highest antiquity, although it is described for the first time in the works of Ambrose Paré. This apparatus is shown in Fig. 191, and described as follows: it is composed of a wooden peg, *B*, the lower extremity of it being enlarged

and flattened to furnish a base of support. The upper portion of the peg, *B*, is received into a socket which forms part of the cone-shaped piece of linden wood, *A*, the diameter of which increases from below upwards. The upper part of the linden wood cone terminates in two splints, an internal and external. The internal splint is not carried above the middle of the thigh, while the external extends upwards to the neighborhood of the crest of the ilium and is fastened around the pelvis by the aid of a cushioned leather belt. A cushion placed between the two splints is destined to receive the knee which alone supports the weight of the body. A leather strap passes from the external splint to the internal, embracing the lower part of the thigh and assuring the immobility of the stump. The classic peg should not be employed in the case of a submalleolar amputation, because a long stump flexed at a right angle inconveniences considerably the maimed, who only moves at the risk of striking against the surrounding objects and who is not even able to be seated without taking a difficult position. The inconvenience and the pain which are experienced in these cases, when the maimed are compelled to wear the peg leg, are such that these unfortunates sometimes earnestly implore another amputation of the leg at the point of election. It is therefore indispensable to give these unfortunate cases an apparatus in which the leg is placed in extension, and in which the normal articulation at the knee is utilized. This question has pre-occupied the minds of surgeons more than many others, although it is certain that submalleolar amputations are less dangerous than the amputation of the leg at the point of election.

Fig. 191.

At the present day artificial limbs are made in great perfection, and these instruments may be advantageously applied in

certain cases, notwithstanding the leg has been amputated below the anterior tibial tuberosity. In order to arrange properly for the investigation of this subject, we will study successively the apparatus which has been proposed for the amputations in the lower third of the leg, and that which has been employed for the amputation performed above this point.

Apparatus for Amputation in the Lower Third of the Leg.

The Hollander, Van Solingen, who was one of the first, after Lowdham, to practise submalleolar amputation, enabled the maimed to walk with the following apparatus: a simple wooden foot, which was kept in its place by two slender and polished metallic splints on the sides of the leg aided by the screw. Dionis says: "The maimed on whom Van Solingen had operated and to whom he had applied his apparatus walked as well as with natural limbs." Although the description of Van Solingen's foot is very incomplete, it is clear that the weight of the body rested directly on the stump. In 1696, Verduin, recognizing the disadvantages which are inseparable from such a system, determined to take his point of support no longer from the stump, but from the thigh as is still done to-day by Mathieu, Bechard, and Palmer. We will pause for an instant at the leg of Verduin, because it marks an epoch in the history of prosthesis of the lower extremities. This leg is shown in Figs. 192, 193, 194, and we will describe its various parts.

Fig. 192 represents the general appearance of Verduin's artificial leg, and a peg which may be substituted for the artificial foot. Fig. 193 shows Verduin's leg applied; while Fig. 194 represents the chamois-skin bag in which the stump is placed. This leg is composed of a wooden foot, *A*, a boot or copper sheath, *B*, split open on both sides to permit the entrance of the stump, and an armor for the thigh, *F*, made of stiff double leather. The boot is attached to the foot by a ring, *D*, and is fastened to the other parts of the apparatus by two iron splints, *E*, articulated at *H* in such a manner as to permit the move-

ments of the knee; and, by the aid of the leather straps, the boot and armor are accurately applied to the stump. Sometimes the artificial foot is replaced by a simple peg. The stump does not rest on the bottom of the apparatus; and the prolon-

Fig. 192.

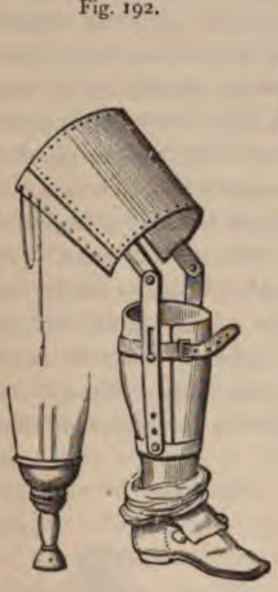


Fig. 193.

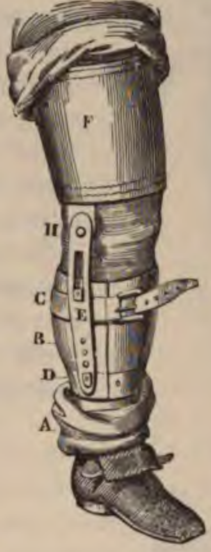


Fig. 194

gation of the point of support prevents the twitchings that the compression of the integument would otherwise exercise on the cicatrix. In order to protect the stump more surely from all injury from pressure, Verduin enveloped the leg and thigh in a layer of chamois skin. This apparatus, with the exception of the articulation which was not eccentric, was truly irreproachable as a principle. The condition of the industries of the seventeenth century had not reached such a point as to allow the question of making this instrument lighter to be raised. Ravaton without doubt found Verduin's apparatus too heavy, and therefore constructed in 1775 an artificial instrument in which the weight of the body was supported by the surface of the leg. This apparatus is represented in Figs. 195, 196, and 197.

Fig. 195 shows Ravaton's apparatus for submalleolar amputations. Fig. 196, the stump placed in the sheath, and Fig. 197 the laced apparatus, and the appearance of the limb when ready for service. It is sufficient to look on the plates together to be convinced that the stump, resting on a soft cushion, does not sustain pressure; and that it is suspended in the apparatus which is accurately fitted to the leg and the tuberosities of the knee. A little later Wilson made an apparatus of the same sort as that of Ravaton, but still more perfect; the weight of the body rested on the condyles and the

Fig. 195.

Fig. 196.

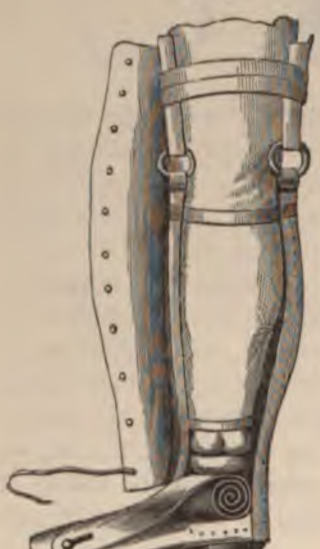


Fig. 197.

patella. I shall not stop at this point to describe all the artificial legs successively proposed by White, of Manchester, Briminghausen, Vacca, Berlinghieri, Salemi, of Palermo, and Serre, of Montpelier, because they are based on the same principles as the preceding, and, consequently, possess only a historic interest. It may here be stated, that before the commencement of the present century, efforts had been made to cause the maimed, whose legs had been amputated in the lower third, to walk by taking the point of support from the stump, then by taking it from the thigh, again by taking it from the circumference of the leg, and afterward by taking it from the inferior border of the patella and the tuberosities of the tibia. In our day we find the same principles utilized because the artificial limbs cause the weight of the body to rest more on the stump, the patella, and the tuberosities of the tibia than on the thigh; in the mean time, believing that the point of support on the thigh exerted too strong a circular pressure, Goyrund, of Aix, seconded by the orthopædist, Mille, created a new class of artificial limbs in which the weight of the body rests on the appendages of the coxo-femoral articulation—more especially on the tuberosity of the ischium. Goyrund's apparatus is represented in Fig. 198, and is composed of four metal splints, of which two are for the leg and two are for the thigh. These splints, slender, light, and grooved, jointed at the level of the knee by an articulation similar to that in the head of compasses. The internal femoral splint is extended upward to the base of the thigh, while the external is carried upward to the

Fig. 198.

crest of the ilium. The first is straight, whilst the other where it comes to the great trochanter describes a curve which passes in front of this process, and is finally fastened above it by a leather belt which embraces the pelvis. The two femoral splints are also united at the base of the thigh by a sheet-iron zone which is four inches wide, covering the gluteal fold, the posterior border of which corresponds to the base of the thigh, and is turned slightly outward, furnished with a cushion, and serves as the principal point of support. Above the knee the two femoral splints are united anteriorly by a metallic semi-zone, which is applied accurately to the anterior part of the thigh. This zone is afterwards completed behind by a piece of leather or canvas, which is fastened to the posterior portion of the metal semi-zone by the aid of laces. The two-leg splints are united in front from the bottom of the boot upward to the depression formed by the projection of the condyles of the tibia by another leaf of sheet-iron, which embraces the anterior part of the stump, and is neatly fitted to the same. The posterior part of this stump is embraced by a leather half leggin contiguous to the skin, which covers the anterior sheet-iron plate and both the leg splints in front. This half leggin is brought together and fastened by a lace behind the stump and behind the external leg splint. The stump is thus solidly fixed in the apparatus, and its extremity rests at some distance from the bottom of the boot and sustains no pressure. Inferiorly the leg splints are firmly fastened to a piece of wood about two inches high, which forms the lower portion of the leg, bulging slightly outward to imitate the malleoli, and descending over the sides of the articulation at the bottom of the limb to the foot. The bottom of the leg, and the lower portions of the leg splints, are articulated by a deep angular hinge joint, with a foot formed of two pieces of wood, the one movable on the other, the larger representing the tarsal and metatarsal regions, and the smaller the toes. The articulation of the foot with the leg, and the two pieces of the foot with each other, are furnished with springs arranged in such a style that, in the state of repose, the anterior

extremity of the foot is slightly raised, and the digital piece is on the proper plane with the plantar face of the principal piece.

The apparatus of Mille was incontestably superior to all those which had preceded it, and nevertheless the maimed were incapable of using it without suffering great fatigue while walking or even when standing. This was recently explained; the leg of Mille tends constantly to flexion at the articulation of the knee, and consequently considerable muscular effort was required to maintain it in the straight position. An effort was made to correct this defect by adding to the apparatus a slot at the level of the articulation of the knee. This slot only permitted flexion for the sitting position; but then the advantages of the movements of flexion and extension while walking were entirely lost. Jalome endeavored to preserve these movements. Delacroix added a spring intended to aid the action of the extensor muscles, but this spring was imperfect as it obstructed the flexion. Ferdinand Martin, profiting by the experience of his predecessors, very quickly proposed a more convenient artificial leg.

The first one introduced by him took, like that of Mille, its principal point of support from the tuberosity of the ischium and, like that of Mille, embraced accurately the entire surface of the thigh. The improvement consisted in a spring similar to the mainspring in a gunlock, placed in the articulation of the knee, at the point where the femoral splint meets the leg splint, these splints are arranged in such a manner as to favor the extension without obstructing in the least degree the flexion, consequently the patient while walking or standing has only to make a slightly increased muscular effort to maintain the limb in its erect position. In a second trial, Ferdinand Martin substituted for the gunlock mainspring a much more simple and less fragile mechanism; a little later his studies of the normal articulation of the knee resulted in providing a new mechanism of the greatest simplicity, which has produced a complete revolution in the art of prosthesis of the lower limbs. The value of the improvement and the accuracy of the principle have since been lauded by no less an authority than Cruveilhier. By an

attentive dissection F. Martin recognized that the lateral ligaments of the knee-joint were inserted very much behind the axis of the limb, and that an iron pin, passing behind these two ligaments, traversed at the same time the two crucial ligaments. The centre of the movements of the articulation of the knee is consequently behind the axis of the limb; and it follows from this single circumstance, said F. Martin, that when the limb is extended and the weight of the body thrown on the knee, that this of itself tends to carry it behind, but the lateral ligaments are opposed to it, without which the intervention of muscles would be necessary; and consequently the economic action of the parts is thus preserved. The reality of this fact may be demonstrated by the extreme mobility of the patella in the standing position, which certainly shows the perfect relaxation of the extensor muscles. It therefore follows that in order to give complete stability to the artificial limb while standing, it is sufficient to support the articulation of the leg and femoral splints behind the axis of the limb.

But another truth proceeds from this anatomical fact, viz., locomotion is possible without the participation of the extensor muscles of the leg. During the walk, in fact, when the knee is brought to the front, the leg, said Ferd. Martin, will be found suspended at the centre of movement, and, by the force of inertia, rests for a moment obliquely suspended behind; it is therefore elongated a certain number of degrees from the perpendicular, weighed down from its point of suspension. Propelled by the weight towards this perpendicular, it balances itself in front, in a word, it oscillates, like the movements of a pendulum, on its point of suspension, and comes to the vertical; but the impulse which it has received in the movement of projection brings it to the front, a certain number of degrees, almost equal to that which it has passed over to come to the perpendicular, and it has described the arc of the anterior circle which is nearly equal to the posterior which it has passed; and the result of this is that the axis of the leg is brought to the prolonged axis of the thigh, and consequently the whole limb is found in extension.

A certain number of pathological facts mentioned in "*me-*

moire sur la resection du genou," confirms the reality of this physiological mechanism.[1] While it is possible to walk without the intervention of the extensor muscles with a natural limb, it is also clear that it might be the same with an artificial limb, if the latter possessed the capital arrangement of the knee, that is to say, if it placed the centre of the articulation behind the axis in this joint. It is the discovery of this principle, which teaches us *to throw the centre of the articulation behind the axis*, which constitutes the *great merit* of Martin; it has been argued, it is true, that this wise orthopædist has not constructed the first apparatus with an eccentric articulation, but this means little, he suggested the principle and this was the chief point. Fig. 199

Fig. 199.

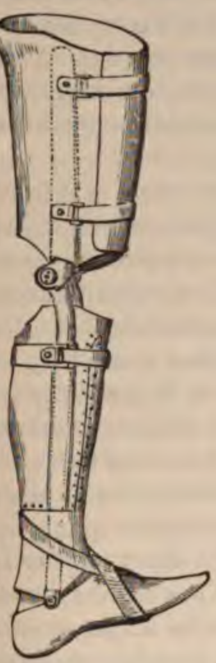


Fig. 200.

represents the artificial limb made by Martin for a submalleolar amputation, with a movable articulation without any spring.

[1] E. Spillmann, Archives générales de médecine, June, 1868.

This apparatus is composed of two femoral splints, articulated at the level of the knee with two leg splints; in order to bring the articulation of this joint behind the axis of the limb it was sufficient to make these splints describe a curve backward at this articulation. A leather sheath, fastened to the femoral splints, embracing accurately the thigh and extending upward to the level of the ischium furnishes a point of support. Another leather sheath embraces neatly the leg in such a manner that the stump does not shake, so that it rests without the least pressure on a soft cushion. The lower part of the leg splints are articulated with the foot which is maintained in a permanent state of flexion by a spring. That which I have already said renders it unnecessary that I should enter into any of the details of the action of Martin's leg. I would only remark that the restoration of the foot is only an object of luxury and does not render any more service than a simple peg leg. F. Martin understood this defect, when he made the legs terminate in a simple peg, legs considered even as useful as those with an artificial foot.

The apparatus of Charrière, which is shown in Fig. 200, resembles Martin's in its principal arrangements, although it terminates in a more useful foot. Here an artificial muscle, *C*, descends from the armor, *D*, to the heel, *A*, counterbalancing the action of the anterior spring, *B*, and permits the foot to rest, on the entire plantar surface, when the maimed is standing. When the healthy leg is brought to the front in walking, the artificial limb remains strongly extended, in such a manner that the foot remains in extension, but as soon as the artificial foot leaves the earth in its turn, it flexes at the knee, the tendon is slackened, and the foot raised by the action of the anterior spring, in order that the toes may not strike against the earth or any foreign body while the maimed is walking. Thus far the movements of nature are perfectly imitated, but it is no longer so as in the last step of the walk, at the moment when the artificial foot comes anew to rest on the ground, a difference is observed. Then, in fact, *in the natural walk*, the leg is extended on the thigh at the same time that the foot is slightly flexed on the leg,

in such a manner that the heel is the first to rest on the ground. With the artificial tendon, it cannot be so; at the moment that the leg is extended on the thigh, the foot is forced to be extended also; the result of this is that the foot is supported on the sole at its point, at first, instead of commencing at the heel, and thus gives rise to a want of precision in the gait and further embarasses the maimed in walking. By practice the results may be modified, be it by learning to walk in a certain style, be it in accordance with a certain predominance of the anterior spring; but it is certain that with all these artifices the artificial foot renders no more service than a non-articulated peg, terminating the leg portion of the artificial limb. Many of the maimed prefer even this simple peg. I insist on all these details, because it is indispensable, when it is employed in an amputation of the lower third of the leg, that the artificial foot possess the natural movements if it is to serve a laborer advantageously. The English and Americans have considerably modified the artificial legs, have generally abandoned the pelvis as a point of support, and have sought to make their apparatus hold by fitting it accurately to the general configuration of the inferior extremity, by taking their principal points of support from the contour of the thigh, the tuberosities of the tibia, and the border of the patella. Mathieu and Bechard have adopted this modification, which we do not consider a progress, and we will give our explanation on this point after having described the principles of this apparatus. Recently the American, Bly has pushed perfection to its last limits by inventing a new mode of artificial tibio-tarsal articulation. Among the artificial limbs taking their support from the contour of the thigh, the tuberosities of the tibia and the inferior border of the patella, one should cite especially that of Palmer which is represented in Fig. 201.

The leg of Palmer is composed of a wooden case, enveloping accurately the thigh, and, being united at the level of the knee by an articulation situated behind the axis of the limb with a wooden sheath representing the leg, in which is enveloped the stump. This second portion terminates at the level of the tibio-

Fig. 201.

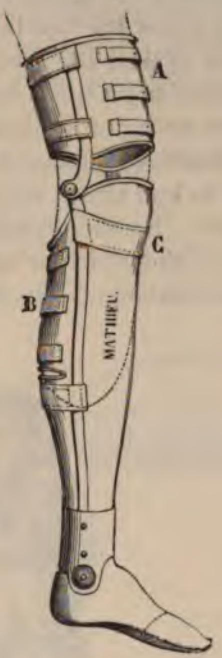
tarsal articulation in a rounded surface which is sunk in a cavity in the posterior part of the artificial foot. These two parts, foot and leg, are maintained in place by a metallic pin traversing the transverse diameter of the articulation. The movements of the knee are like those of Martin's, since the principle is the same; whilst the movements of the foot on the leg are produced by the aid of springs placed within, the one in front and the other behind the leg; the latter of these springs, destined to represent the action of the gastrocnemic muscle, one part being inserted above into the middle of the leg and below into the heel, while still another part extends from the middle of the leg to the instep. The anterior splint maintains the point of the foot slightly raised, in order that it may not strike against any obstacles; the posterior spring holding the heel, communicates to the artificial limb, at the moment when the latter quits the ground, an elasticity which favors walking and contributes in a high degree to hide the deformity. Among the French, Bechard and Mathieu have followed the example of the American constructors in taking the points of support on the thigh and knee, and their artificial limbs are represented in Figs. 202 and 203.

These artificial limbs differ from Palmer's in this, that the sheath which envelops the thigh and leg is of leather, and may be tightened at will by the laces or leather straps. In both, the action of the anterior has a slight predominance which keeps the point of the foot slightly raised, but still the service here rendered by the foot is trifling. From other causes, even

though the movements of flexion and extension are perfectly natural in the artificial foot, the problem is not solved; it is necessary in order to imitate nature that the artificial foot

Fig. 202.

Fig. 203.



possess the lateral movements. Without doubt the tibio-tarsal articulation is an enarthrodial joint, not only possessing flexion and extension, but is seconded by the lateral movements of all the tarsal articulations. These lateral movements are necessary, even indispensable, in an artificial limb, not only as a response to an ideal donation, but to permit the foot to incline in every direction instead of reposing throughout its entire plantar surface on the earth under all circumstances. Let us examine, in fact, what occurs in a limb unprovided with lateral movements: the maimed strikes the foot against a pebble, or an inequality of the

earth, the foot has not the power to move aside, rests no longer on its plantar surface, but on its internal or external border, and the cripple is exposed to a fall. Furthermore, as the artificial limb is inflexible from without inward in its whole length, consequently the stump must become more or less inclined in order to follow the foot in such a manner that it comes to bear painfully against the lateral walls of the sheath. In order to avoid this danger it has become customary to cover the stump with one or more cushions, according to the style of Verduin, lateral pressure is produced, the parts become atrophied, and it will not fail to lead after a while to accidents of a more or less serious character. But there is more than the maimed is willing to admit in the position which he takes in the performance of heavy work. An examination of Fig. 204 shows the position taken by the

Fig. 204.

laborer at the anvil. It should be observed that here he brings the left foot to the front, while the right is inclined behind, and placed nearly at right angles with the left. Supposing the right leg had been amputated, then if the artificial foot did not possess lateral movements, it could not in this situation apply its

sole over the entire plantar surface to the earth, but could only rest on the internal border, and would not consequently give that firm point of support in which the workingman could confide. Douglas Bly, of Rochester, has overcome all these difficulties by merely making a mortise tibio-tarsal articulation traversed by a metallic pin, assuring the play and fixidity of the different elements. This new and important invention with its various modifications is represented in Figs. 205, 206, 207, 208, 209, and 210.

Fig. 205.

Fig. 206.

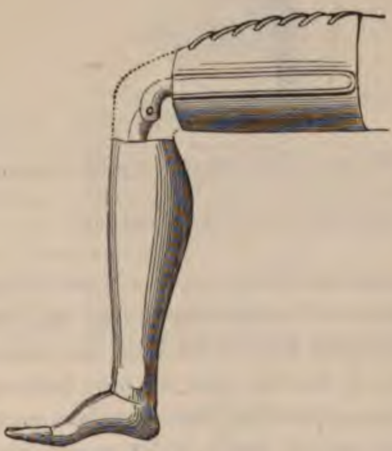


Fig. 205.—A longitudinal cut of the artificial leg. (This cut represents an apparatus intended for an amputation of the thigh; we will explain in the text the modifications which should be made when it is to be applied in amputations of the lower third of the leg.)

Fig. 206.—The apparatus applied to an amputation of the leg. (Articulation of the knee eccentric to axis.)

Fig. 205 represents a vertical cut of Douglas Bly's artificial leg; the polished crystal ball, enveloped in a vulcanized rubber

sack is indicated by the letter *b*, the letter *a* indicates three of the four rubber stops which are traversed by the tendons, *c*, which are also rubber, and these tendons represent the natural muscles of the leg. At their upper part these rubber tendons, *c*, are terminated by a sort of screw which permits the force of the spring to be regulated at will. Fig. 208 represents a hori-

Fig. 207.

Fig. 208.

Fig. 207.—The apparatus applied to an amputation of the leg. (Articulation non-eccentric.)
Fig. 208.—Tibio-tarsal articulation.

zontal cut of the leg at a level of the tibio-tarsal articulation; it allows to be seen the crystal ball placed in the hollow cavity of the upper part of the foot, the hemispherical cavity of the lower end of the leg, and the four tendons which bind it to the foot. It is evident that these tendons permit the bottom of the foot to rest on the earth, in its whole surface, whatever may be the directions which may affect the artificial limb; the leg rolls on the ball in order to take a convenient position, and that mechanically without any voluntary aid on the part of the maimed. Fig. 209 shows the foot resting on the ground throughout its whole extent, on a plane very much inclined from behind forward. Fig. 210 represents the artificial foot as accommodating itself in repose on an accidental object, such as a pebble, like a

natural foot without the rest of the apparatus being changed. Figs. 206 and 207 represent the apparatus applied in the case

Fig. 209.

Fig. 210.

Fig. 209.—The plantar surface of the foot resting throughout its whole length on an inclined plane, inclination being from behind forward.

Fig. 210 —The artificial foot inclined laterally at the moment when it came in contact with a pebble. The description of this apparatus commences with the tibio-tarsal articulation, which is constituted with an ivory or crystal ball received into a spherical cavity, one-half of which is made at the expense of the inferior end of the artificial leg, and the other half at the expense of the upper surface of the foot; the springs, *C*, four in number, two lateral, one anterior, and one posterior, passing through the leg into the instep, represent the forces which maintain the plantar surface of the foot constantly applied to the earth whatever may be its situation elsewhere.

of a leg amputation. One grave objection has been made, the foot being only fastened to the leg by the springs loses all solidity if one of these should be broken, and a fall would be inevitable. Now these springs are submitted to an enormous pressure. Bly replied to this objection by saying that the springs being made of compressed rubber, no force was capable of breaking them. Experience has confirmed this assertion. We will remark that in the illustration which we have given Fig. 205), the rubber springs ascend too high, in the interior of

the artificial limb, for a case of amputation in the lower third of the leg. But, as it may be made to descend much lower, the apparatus is made applicable for an amputation, if it were performed five centimetres above the inter-articular line.

The artificial limb of Camille Myops is constructed on the same principle as that of Bly, but is still more convenient in cases where the amputation is performed very close to the tibio-tarsal articulation. This apparatus is shown in Figs. 211, 212, 213, and 214.

Fig. 211.

Fig. 212.

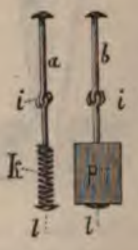


Fig. 213.

Fig. 214.

The leg, *A*—linden wood—is surrounded at its upper part by a metal ring, *d*, from which start two splints, *f*, which ascending at the sides of the knee, are attached to armor of the thigh, *C*; these splints are articulated eccentrically at *g* on a level with the tibio-femoral articulation. The foot, *B*—linden wood—is

articulated with the toes by means of a hinge and spiral spring: in its superior part it presents a hemispherical excavation, corresponding to an identical excavation hollowed out of the bottom of the leg. In these excavations play the ivory balls, the volume of which is calculated in such a manner that a space of one-fourth of an inch around it separates the foot from the leg; this space permits the foot to incline or move in any direction on the leg during the movements which bear on the ivory ball. The springs situated about the tibio-tarsal articulation completely assure at the same time its solidity and mobility, the same as in Bly's apparatus. Each of these four springs is composed (Fig. 212) of a brass stem, *k*, formed into a spiral spring, and articulated at *i* with another brass stem; the stem, *a*, is lodged in the lower part of the leg, and the spiral spring, *k*, in the foot; a screw, *l*, placed below the spiral spring permits the tension to be regulated. Fig. 213 makes perfectly easy this system; *h* represents the ivory ball, *i i i* the articulation of the springs which are situated on a level with the open space between the leg and foot; *k k k* the springs lodged in the foot; *l l l* the screws by the aid of which the tension of the springs is regulated. Fig. 214 shows on the plantar surface of the foot the regulating screws, *l l l l*; in front the toes, *B*, are united to the tarsus by a hinge. The spring placed between the toes and the plantar surface of the foot is shown in Fig. 213. The position of the springs seems to me to be better chosen in the apparatus of Myops than in that of Bly, since they occupy only a very small space in the leg, and they can be also utilized in cases of intra-malleolar amputations. It is evident that we can substitute the rubber springs of Bly for the metal springs of Myops, as they have the advantage of being noiseless while the patient is walking, though they are endowed with less elasticity.

This is, however, here only a very unimportant question. We ought here to call attention to the fact that something analogous to that which has just been mentioned was done in France a long time ago. General Daumesnil, who commanded

at Vincennes, in 1814, wore a leg constructed on the same principle as that of Bly. In all respects an artificial limb with a movable articulation of the foot is in every sense infinitely superior to all those which had been previously made. This fact has been announced by the military commission of the United States who were convened for the purpose of studying and determining the apparatus which could be most advantageously employed for the relief of the maimed in the late terrible war of secession. We have no doubt that in the generalization of the artificial limbs, the greater part of the objections only fail which are addressed to the submalleolar amputation. Unfortunately, it is especially for the workingman that the lateral movements are required at the tibio-tarsal articulation, and he is not able to procure Bly's apparatus, which costs an exorbitant price; it is, therefore hoped that mechanics will employ their ingenuity in giving to humanity a similar but less expensive apparatus. The foot proposed by the American, Mr. Mark, is shown in Fig. 215, and may be able to supply the want up to a certain

Fig. 215.

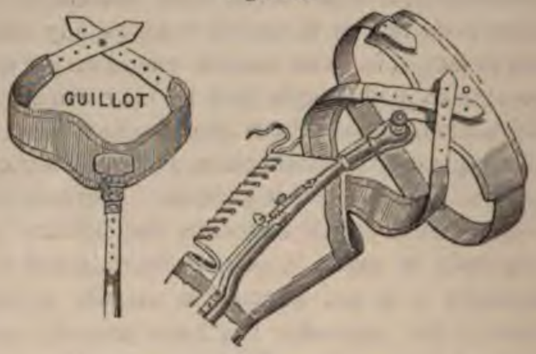
point. This foot is composed of a piece of light wood, the form and size of which are represented by the dotted lines traced on the above figure. This wooden mould is surrounded on every side by a considerable mass of rubber which assumes the general form of the foot. The rubber foot is united with the leg with which it forms a single piece, without mobility at the level of the tibio-tarsal articulation. The elasticity of the rubber permits it to accommodate itself to the form of all the surfaces with which the foot may come in contact, and it fulfils perfectly, *they say*, the mobility of the tibio-tarsal articulation supplied with the springs. American surgeons seem to have a good opinion

of this rubber foot, which certainly ought to be experimented with in France, because it is absolutely necessary. *I cannot repeat it too often*, to give to persons who have submitted to an amputation in the lower third of the leg a foot resting flatly on the earth, in all possible movements.

Another grave question remains to be debated, to determine whether the apparatus should take its point of support from the pelvis, following the method of Gayraud, or, on the contrary, is it more convenient to conform to that method which at the present time is called English, although it originated with Verduin. Theoretically, it seems much more rational to make the weight of the body rest on the pelvis than on any other part; the maimed, in fact, is in some manner seated on the extremity of his apparatus in such a style that he may remain standing in this position a long time without causing much fatigue, results very valuable, especially to workingmen, who by their occupation, remain nearly all the day in this position. It is also worthy of attention that the flesh which surrounds the ischium has been prepared expressly by nature to support the weight of the body, and consequently it is not disposed to ulcerate provided the upper portion of the apparatus has been properly cushioned. The ischium as a point of support presents another advantage, the extremity of the artificial leg comes finally to rest in contact with a neighboring projection, the whole of the apparatus does not require to be firmly fastened; it is sufficient that it be accurately applied to the surface of the stump. It is true that the objection has been raised that the wounded, who are accustomed to use Martin's, Charrière's, or other artificial limbs constructed on the same principle, after a while, the parts, the integument of the thigh, etc., are pushed up in such a manner as to make a thick cushion which may hang down over the upper part of the apparatus. It was to guard against an accident of this kind that Mathieu took the point of support on the thigh in one of his first limbs. This objection is not serious, it is always possible to avoid the formation of this cushion, by giving to the sheath *of the thigh at the upper part* a sufficiently large bell or mouth opening, or, perhaps, more certainly by wrapping the

stump in chamois skin from its point upward to the ischium; if necessary, even a pair of drawers, similar to those manufactured by Lebellegnie in the case of an amputation of the upper part of the thigh. It enables us moreover to avoid the inconvenience arising from too close a proximation of the apparatus to the point of support on the ischium, and is in harmony with a new system presented to the Surgical Society, in 1868, by Leon Le Fort. The apparatus now under consideration was manufactured by Guillot, and is represented in Fig. 216.

Fig. 216.



The most important part of this apparatus, said Le Fort, is its method of ischiatic support. The curved plate which rests on the ischium, and which is *reproduced in part in this illustration*, acts by means of a triple joint on the movements of flexion, whatever they are, and also on the movements of rotation; the plate is closely applied to the ischium, and remains constantly in contact with it, whatever may be the position of the limb. This arrangement avoids the irritation which may be produced by the ordinary apparatus. This system is imitated in the one that L. Le Fort has adopted in his apparatus for the treatment of coxalgia. The artificial limbs ascending to the ischium, are therefore useful without having serious inconveniences; the thigh armor should be longer than in those artificial limbs which are limited to embracing these parts, and should also be firmly applied, and consequently the latter may be made

lighter. But it may also be remarked that the artificial leg which presents no other point of support than the surface of the thigh, would be simply worthless. Surgeons have not yet learned how to constrict sufficiently the cone of the thigh, so that the apparatus may not be constantly pushed upward carrying with it the flesh, which would be formed into a cushion above the leather armor. Such a constriction of the parts would be very painful, and, moreover, it would be dangerous.

All the artificial limbs which are known to-day as "*thigh supporting*," do, as a matter of fact, take their principal support from the tuberosities of the tibia and the inferior border of the patella; in reality, the sheath surrounding the thigh is not the essential part, but only an adjuvant. There are certainly very few artificial limbs made in which the armor of the thigh is accurately moulded to the parts, and it should not be done, because it would assuredly draw the flesh upward on the leg; and consequently open the cicatrix, or at least, after the apparatus had been in use a short time, it would be liable to produce these inconveniences. When the principal point of support is at the ischium, it is too far away from the cicatrix to be possible to produce this effect. Therefore, in our judgment, the designation of any apparatus as thigh supporting, is a misnomer, and further they can only be regarded as an improvement on the ideas put forth by Gayraud of Aix, and the only thing that can be said in their favor is that they are extremely light. Nevertheless this advantage is sufficiently important that they should not be absolutely rejected, and they are perfectly adapted to the wants of rich persons, who desire to work but little. But they ought never to be supplied to a laborer, even though the appearance of the stump inspires no other fear than that of seeing the cicatrix torn open throughout its length, and then the artificial limb ought not to be too tightly adjusted. But if the stump present these conditions, if it be well enough cushioned to support the weight of the body without the production of severe pain, and without ulceration, it is here possible to have recourse to a much lighter, more beautiful, and simpler apparatus than all those which we have previously

mentioned. The persons who had their limbs amputated by Solinger, walked perfectly by the aid of a simple boot, according to the statement of Dionis.

In our time there has been seen at the Belgian Academy of Medicine a tailor by the name of Goëns, whose leg was amputated through the lower third, who was able to travel several leagues on foot with a sort of boot which he had made for himself. Several maimed, walking with an apparatus of the same kind, have been presented to the Surgical Society during the last few years. It is possible that these facts will be multiplied so much more as the posterior flap amputation is advantageously practised, including, as was suggested, by Marcelin, Duval, and Voillemier the whole of the tendo Achillis. It is evident that, when these fortunate circumstances present themselves, it will be necessary to know how to take advantage of them, because the apparatus which does not extend above the knee is at all times more convenient to wear and less expensive than the others. Among the artificial limbs which have been described, the most simple is that of Biggs, which is shown in Fig. 217. It is composed of a sheath fitting accurately to the

Fig. 217.

leg, and bound to a sort of garter surrounding the thigh by the intermediation of two metal splints; these splints and the garter

have no other object than to prevent the apparatus from slipping. The artificial foot is movable on the leg by means of two springs, the one anterior and the other posterior. Biggs has remarked that this apparatus was acknowledged by all to be the best for amputations in the middle of the leg. He also observed that when amputations are performed very low down, the anterior border of the stump, by reason of the length of the arm of the lever, is very much exposed to injury during progression; to counteract this it is proposed to cut a fenestrum in the apparatus at a corresponding point. Charrière has made an apparatus which does not ascend above the knee. Here the weight of the body is supported not only by the stump, but also by the inferior border of the patella and the tuberosities of the tibia. This substitute, which is designated "Martin's apparatus," for medio-tarsal amputations, is composed of a leg ascending up to the patella and laced behind; the leg terminates in an artificial foot which is united to the limb by a mortise; and if one desired to render this instrument less expensive he might substitute for the foot the simple peg. On the interior of the leg, there is found a metal plate descending on the outer and inner side of the limb, so shaped as to form a stirrup below the stump at the distance of several centimetres. This metal plate gives an attachment superiorly to a large leather thong which surrounds the artificial limb immediately below the stump, thus furnishing a firm and elastic point of support at the same time. An elastic cushion placed between the metal plates and the leather thong aids in softening down the pressure. This apparatus has been thus employed for Chopart's amputation, and also for amputations at the tibio-tarsal articulation. It may be employed when the stump is somewhat tender or sensitive under pressure, although not disposed to ulcerate. If, on the contrary, the stump is not all indolent, and is also well cushioned with the soft parts, then the case will succeed better in Mathieu's apparatus, because of its greater simplicity.

Mathieu's apparatus, which is shown in Fig. 218, is composed of a moulded leather leg, sustained by two splints, *B*,

Fig. 218.

fastened to a wooden foot; from the upper part of the leg starts two leather straps which are joined to a band, *A*, surrounding the thigh, immediately above the condyles of the femur. The object of these straps is to prevent the foot from slipping. It is, above all, necessary, when the boot is employed, to envelop the stump in a cushion or a chamois-skin sheath which prevents all immediate contact. It is advantageous to apply these wrappings about the limb in such a manner that all irregularities disappear. A considerable number of persons on whom amputations had been performed above the malleoli have been fortunate enough to walk with the boot which we have mentioned; we however think that this apparatus would render the very best services, if the foot were articulated according to Bly's method, or at least if the foot were made of rubber, like that of Mark.

Amputation of the Leg above the Lower Third.

The English surgeons have not adopted the point of election for amputation, which has become classic in France since the time of Paré, they remove the leg at any point, according to the indications of the case, and it is bound to be right, because it has been satisfactorily shown that an amputation in the middle of the leg is more perilous than a disarticulation at the ankle-joint, and consequently an amputation performed two inches below the tuberosities of the tibia is more dangerous than in the middle of the leg. Besides, an amputation performed in the middle of the leg affords an excellent opportunity for prosthesis. All the American and English mechanics agree in saying, that when the amputation is performed in the middle of the leg or even a little above, that it is more easy to make the maimed walk, in consequence of preserving the extension of the limb and the movements of flexion at the knee. In these cases they

frequently employ in England an apparatus which has been described by Bigg, and which is shown in Fig. 219.

Fig. 219.

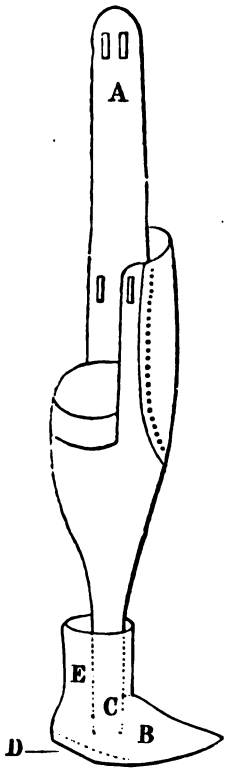
This apparatus is composed simply of a wooden leg, adapted accurately to the stump, and fastened by two leather straps to a leather band, which surrounds the thigh above the knee, while inferiorly the leg terminates by a simple peg. This apparatus costs but little, and is one of extreme simplicity, and at the same time preserves all the natural movements of the knee; but unfortunately it is only applicable when the stump is in such an excellent condition as to be able to support the requisite amount of pressure without being damaged. This is not so in the large majority of cases, so we are almost always obliged to have recourse to the artificial limbs which take their point of support from the thigh or the ischium, as we have already mentioned in describing the amputations of the lower third of the tibia. These can be employed without any modifications, with by far the greatest facility, on account of less length of the arm of the lever; and we should have less if the cicatrix was situated in front, because being made by a long posterior flap it would be less liable to come in contact with the apparatus in the movements of extension. When an amputation is performed

at the point of election, nearly everybody is satisfied to endeavor to make the maimed walk while resting the weight of the body on the knee, flexed at a right angle on the cushion of the classic peg; nevertheless there has been a slight attempt made to modify this primitive apparatus, and the progress of prosthesis has been so considerable that a certain number of the maimed have been enabled to walk with a leg placed in extension, by utilizing the normal functions of the knee-joint absolutely as if the operation had been performed on the inferior part of the leg. We have here consequently two classes of apparatus to study; an apparatus with which the maimed walk while the leg is flexed, and an apparatus with which the maimed walk when the limb is extended.

The type of the first is the classic peg (Fig. 191), and is still adopted by the majority of the maimed, especially the laboring class. It is an instrument of such simplicity that it may be constructed by the most modest artist, and consequently it is not expensive, it is very light and gives a firm point of support for walking. But with these advantages the peg leg presents such serious disadvantages that it has long been sought to graft on it some useful modifications. This leg is very inconvenient in the sitting position, especially because the band surrounding the pelvis is pulled on by the external splint and is carried backward. Chelius has claimed that some surgeons have remedied this inconvenience by fastening the external splint to the thigh; but this point of support did not afford a sufficient guarantee of stability, and it is more simple to break the external splint at a level with the coxo-femoral articulation, and to place at this point a bolt which the maimed may draw out while sitting and introduce while standing. Still in the sitting position the peg leg makes a very strong projection to the front, which prevents the maimed from being seated in a place, or on seats which are small, such as the theatre or omnibus, etc. Another objection to the peg leg is, that it rests *on the earth by a small base*, that it is liable to be greatly disturbed by all sorts of irregularities, as for instance stones, and again it may sink

deeply into the soft muddy earth. Attempts have been made for a long time to correct this defect by attaching to the peg leg an artificial foot, and de Beaufort has given to this foot a special form for the purpose of facilitating walking. This artificial contrivance is shown in Fig. 220.

Fig. 220.



The apparatus of de Beaufort is composed of an ordinary wooden leg, *A*, which presents at its inferior part a linden wood foot, *B*, a square mortise is made at *C*, receiving the upright, *E*, which is of ashwood. At *D* there is found a flat cork surface supplying the part corresponding to the heel and to the peg of the ordinary apparatus. The curvature of the plantar surface of the foot is arranged in such a manner as to furnish the limb with a continuous point of support, while the body is carried to the front; without this curvature, says H. Larrey, it would be so uniform as to expose the limb to slip. It is easy enough to comprehend that the foot of de Beaufort, not only increases the base of support but also lengthens the stride. Nevertheless it is said that all the maimed do not give their preference to de Beaufort's foot. Some of them say that they know less of the nature of the ground with this foot than with the small surface of the classic peg leg which serves them as a sound. The apparatus of de Beaufort has the advantage over the classic peg leg of masking the deformity, but only in an imperfect manner. It will not be desired by the maimed who appreciate most highly a perfect fac-simile in form. The rich man's leg of Ambrose Paré, which we shall describe in speaking of the amputations of the thigh, proves that this preference is

very ancient. Sometimes there is employed an apparatus, which is shown in Fig. 221.

This artificial limb is composed of a leather sheath enveloping accurately the thigh, and presenting at its lower part a cushioned point of support, *B*, on which rests the knee flexed at a right angle. Two metal splints, an internal and an external, descend along the armor of the thigh and are articulated at a level with the point on which the knee, *A*, rests, with two metal splints making a frame for a leather tube which is of the exact form of the leg. To this tube there is attached a light wooden foot, which the two springs, the one anterior, and the other posterior, render susceptible of the movements of flexion and extension. At the level of the articulation of the knee, directly over the femoral splint is placed a bolt, *D*, which penetrates into a mortise made in the corresponding leg splint; the patient desiring to flex the leg in order to be seated, draws upward the bolt, to give free play to the articulation; when he rises to the standing position, the bolt is pressed on by a spring, when it re-enters spontaneously the mortise. This apparatus, imitating closely the form of the natural limb, is certainly more elegant than the ordinary peg leg, but greatly increased roominess of the clothing is required to hide the deformity caused by the projection of the flexed stump. The most perfect, the second class of artificial legs, enabling the maimed to walk and leaving the limb in extension had not been employed for several years. The probability is that it had been supposed to be too troublesome, when Zavier, the chief mechanic of the house of Charrière, presented himself to the Sur-

Fig. 221.

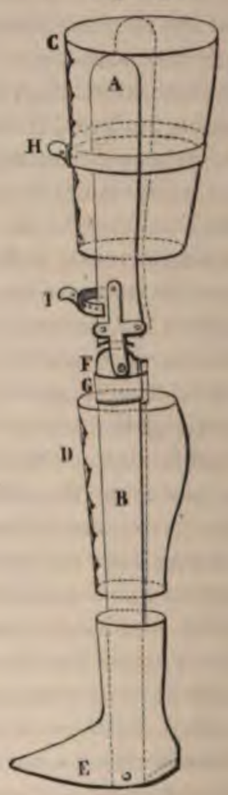
gical Society, Oct. 15, 1857, with this apparatus which he had made. The same day a military captain, wearing a leg of the same kind, was presented to the Surgical Society, and since that date this artificial limb has been generally employed. Consequently in cases of amputation at the point of election the stump may be able to take three different positions: 1st. It may be maintained flexed by the retraction of the flexor muscles; 2d. The alternate movements of extension and flexion may be preserved in all their freedom; 3d. It may be maintained in permanent extension by a more or less complete anchylosis. In the first condition the peg leg or some of its modifications alone can be utilized, at least if the resistance cannot be overcome by orthopædic assistance. Let us remark in passing that a permanent flexion of the stump which holds the limb in a semi-flexed position, ought not to be broken up, or any attempt made in that direction until the cicatrix is *completely healed*, and even no attempts *immediately after cicatrization* should be made to counteract the action of the flexor muscles.

In the second class of cases, all the apparatus employed should take their point of support from the thigh or ischium. These artificial limbs have been previously described in speaking of amputations of the lower third of the leg. The stump is easily placed in the artificial leg of Charrière, Palmer, Bly, etc., since it is in a rectilineal position. The small portion of the leg remaining does not prevent the movements of the artificial knee, since we have explained that these movements, thanks to the eccentric motion, are possible without muscular action, consequently without the intervention of the stump. Therefore the prosthesis is more easy after an amputation at the point of election than after an amputation at the lower third. It is unquestionable that a certain length of the stump gives precision, and otherwise facilitates walking by aiding the pendulum movement which determines the flexion and extension, and by co-operating to a certain extent in the projection of the leg to the front. A stump of a certain length is especially useful to limit the movement of flexion, and this may be increased if the leg is thrown against an obstacle at the moment when it is

flexed, and then the accidental fall of the maimed is inevitable, if the limb is not drawn back with sufficient promptness to regain the equilibrium; if the stump is long enough, it will itself prevent exaggerated flexion, but if it is too short it will not act efficiently. It is therefore necessary to add to the artificial limbs intended to be employed after amputations at the

Fig. 222.

Fig. 223.



point of election, certain mechanisms intended to favor the projection of the limb and to limit its flexion; one of the most simple consists in placing a very large rubber band in front of the apparatus, between the sheath which covers it and the thigh armor; the elasticity constantly tends to extend the leg. This

system is often employed. During last winter Robert and Collin adopted measures for lengthening the stump. They employed an artificial piece, placing the maimed in the same condition as if the amputation had been performed at the middle of the leg. This piece, shown in Fig. 222, is composed of a long cylinder, *B*, which is made of very resisting leather, and is continuous in its upper part with a sheath, *A*, of very soft and flexible leather, laced to the upper part of the leg. This sheath is fastened by two lateral straps to a bracelet, *C*, which surrounds the lower portion of the thigh, just above the condyles. The whole of this apparatus constitutes an artificial stump. This artificial stump, together with the natural stump, almost restores the usefulness of the limb, when we have recourse to a device which was suggested by Robert and Collin. This device consists in covering the stump and the lower part of the thigh with an envelope of chamois skin neatly adjusted, and terminated at the lower part by a leather strap. The leather strap should traverse the whole length of the artificial stump, in order to be attached to a buckle placed at its lower part. The leg having been supplied with an artificial stump is placed in an ordinary artificial limb, and it may be readily understood that this will be able to perform the functions just as well as if the amputation had been performed in the middle of the leg. The movement of extension of the limb will be favored, and the exaggerated flexion will be limited. Exaggerated flexion may be prevented by placing at the level of the articulation of the knee one of the mechanisms which we will describe as appropriate to an amputation of the thigh. Some cripples are contented to walk with a stiff leg throughout its whole length, and have recourse to Count de Beaufort's artificial limb, which is shown in Fig. 223.

The skeleton of the artificial limb is simply composed of two lateral beech-wood splints, divided into two parts at the level of the articulation of the knee, *F*, and united at this point by means of a bolt riveted at both extremities. The leg splints, *B*, are fastened to a leather sheath, *D*; the femoral splints, *A*, are fastened around the thigh by a simple leather strap, *H*. If

the apparatus should be employed for an amputation of the thigh, the strap, *H*, should be replaced by an armor extending up to the ischium. The apparatus terminates inferiorly by an artificial foot exactly similar to that which is employed with the peg leg of de Beaufort; it is movable at the tibio-tarsal articulation. The articulation of the knee is also rendered inflexible when walking by means of a bolt or hook which is raised by the hand to permit flexion for the sitting posture. All the limbs which we have previously described may be rendered inflexible for walking by means of a similar mechanism. The advantages of de Beaufort's limb consists in the ease with which it enables the maimed to walk, which renders it acceptable to the working class. The leg which we are describing was constructed, however, especially for submalleolar amputations; in this case de Beaufort surrounds the lower extremity of the femoral splints by a strap, *I* (Fig. 223), which passes below the patella and furnishes a point of support at the lower border of the bone; furthermore, he does away with the hook at the knee-joint, in order to permit the leg to be flexed while walking. But the articulation of the knee is thrown slightly behind the axis of the limb, consequently the maimed cannot walk and turn about without making considerable and incessant muscular efforts. Let us return to the limb of Mille, that we have criticized from this point of view. Let us add that we would not be able to recommend a foot which is immovable in all its parts; we would prefer a simple peg leg. The maimed whose limbs have been amputated in the lower third, would only be able to wear this foot in those cases where the stumps were admirably made; but they have no need of de Beaufort's artificial limb—a simple half boot is sufficient for them. The immovable tibio-tarsal articulation has fewer inconveniences when it is employed in the case of an amputation performed at the point of election; the stump by reason of its shorter length is less exposed to bend on itself against the walls of the apparatus in the different positions of the artificial limb. It frequently happens that the stump, while fully participating in the natural movements, has a strong tendency to be drawn

backward, and it is to combat this tendency that Zavier has made for himself the apparatus represented in Figs. 224 and 225.

Fig. 224.

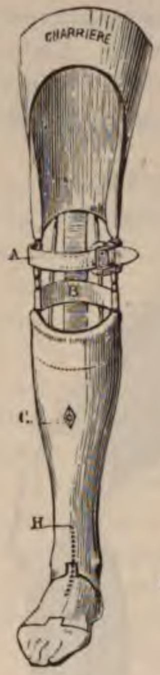
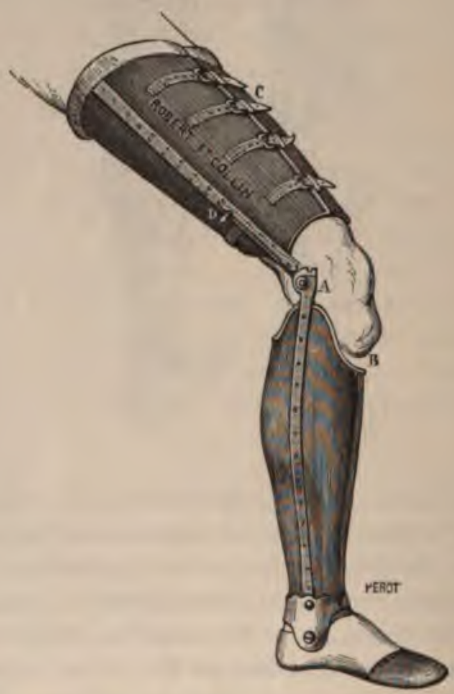


Fig. 225.

The leg of Zavier is constructed entirely of wood, like that of Palmer; but it takes its point of support from the ischium. The lower part of the sheath is hollow for two-thirds of its length in order to diminish the weight of the apparatus; a strap, *A*, passes in front of the thigh, above the condyles, whilst a strap, *B*, is placed behind it, has the effect on the stump of pushing it forward, and maintaining it in a straight position. The articulation of the knee is eccentric and permits mobility while the maimed is walking. The movements of the tibio-tarsal articulation are regulated by Charrière's mechanism, and have been previously described. This apparatus is well combined; and it is certain that Zavier walked perfectly with its aid. It is not

necessary to suppose, however, that the artist has fully accomplished the object which he sought; I have carefully examined an apparatus which he had worn a long time, and I am convinced that the knee should have remained semi-flexed, the marked depression in the superior anterior border of the leg armor is the basis of my opinion. Under some exceptional circumstances, the stump is maintained in an invariable rectilineal position by an anchylosis of the knee. The artificial

Fig. 226.



limbs which correspond to that used in the preceding case are those that we here still employ; only it would be useless to arrange the knee for mobility in walking; it is sufficient that this articulation should be in a condition to be flexed, for the sitting position, by the means of a rod or bolt. The flexion

should be made at the level of the articulation of the knee; if it is properly arranged, there will be placed in the upper and anterior part of the leg armor a fenestrum intended to give passage to the anchylosed stump. Fig. 226 represents an apparatus for amputation of the leg in the case of anchylosis of the knee.

Disarticulation at the Knee.

The prosthesis applicable to disarticulation of the knee has been very little studied up to this time, this doubtless being due to the want of favor with which this operation has been regarded by a large number of surgeons. In the mean time Velpeau, Malgaigne, and Baudens maintain that the disarticulation of the knee is less grave than the amputation of the thigh; the facts gathered during the late American war demonstrate the truth of this opinion. Not only is disarticulation of the knee less dangerous than the amputation of the thigh; but it is also desirable in view of the prosthesis; the large surface of the stump furnishes a firm base of support for the weight of the body; furthermore, the muscular insertions preserved directly or indirectly, by the intermedium of the cicatrix, renders the apparatus conjointly responsible to the movements of the thigh. I am well aware that the hope of having a very large stump may be dissipated, because the condyles may completely atrophy in such a manner that the bony extremity ends by becoming as slender as the diaphysis of the femur sawn in its continuity, but this pathological condition is not so constant as has been affirmed. Arlaud cites the case of a soldier, aged 23 years, who was able to walk after the performance of the tibio-femoral amputation with an apparatus, when the entire weight of the body rested directly on the condyles; this observation is not perfectly convincing, because it was made too soon after the operation, only about a year having elapsed. It is not the same in the case reported by Prof. Thos. Markoe; he operated here on a woman, aged 22 years, who walked perfectly on an ordinary peg leg several years after the disarticulation at the knee.

The American surgeons have observed a large number of analogous cases. It is useful to study the question under this new aspect, because it is readily understood that the facility of the prosthesis becomes an important argument of the partisans of the tibio-femoral amputation; all the world knows that it is much easier to walk with a peg leg than with a peg thigh. If the patient desires a more elegant apparatus than the peg leg, one imitating nature, he may have recourse to Hudson's artificial limb which, it appears, has rendered good service in America. This apparatus is represented in Fig. 227.

Fig. 227.

In this artificial limb the stump rests directly upon the lower part of the thigh armor, which is composed of a concavo-convex posterior splint maintained in place by laces passing in front of the thigh. The lower part of the thigh armor represents accurately the form of the condyles of the femur, and is articulated by means of bolts and metal splints, with a concave surface representing the articular surface of the tibia. A system of laces and elastic ligaments, on the action of which we have not been able to procure sufficient details, favor the extension and flexion of the leg and foot. It is indispensable, in order that the weight of the body should rest directly on the stump, that the cicatrix should be thrown upward and backward; the procedure of Bauden fulfils this indication, but in the mean time it leaves a transverse cicatrix which may be exposed to some painful friction. We prefer, in view of the prosthesis, the procedure of Stephen Smith, who produces a vertical cicatrix situated above and behind the supporting surface of the stump, and hidden in some degree between the condyles. This procedure, very little known, consists in making an incision with a slight convexity downward, which, commencing at the apex of the anterior tuberosity of the tibia, passes around the inner side of the leg, and extends backward to the middle of the bend of the knee; a similar incision is made on the outer side. We,

therefore, have two small flaps which we dissect up by a couple of strokes of the knife, after which we penetrate boldly the articulation. The result is nearly the same as that of an oval amputation. The wound produced is remarkably small; the retraction of the soft parts carries it completely to the posterior part of the thigh, an extremely favorable position for the drainage of pus and for the prosthesis. We will add that this excellent procedure is more easy and rapid than that of Bauden's. If the condyles have atrophied so much that they no longer furnish a sufficient means of support, it will be necessary to have recourse to the artificial limbs which we shall mention as being suitable to amputations of the thigh.

Amputation of the Thigh.

The most simple and the most frequently adopted procedure, to enable those to walk who have suffered an amputation of the thigh, consists in the employment of the thigh armor with the peg leg. This apparatus is shown in Fig. 228. The thigh armor to the peg leg is composed of a hollow cone, the apex being below, terminated by a peg, similar in length, to that employed for amputation of the leg; at the lower part of this cone there is found a fenestrum which is destined to afford passage to a strip of linen which envelops the stump. The cone is padded with hair or wool; its border is invested with a thick cushion intended to give support to the soft parts surrounding the coxo-femoral articulation, especially to the tuberosity of the ischium. The outer side of the cone is prolonged upward by a splint supporting a belt which surrounds the pelvis. We have sometimes seen the maimed, misguided, content with merely introducing the naked stump into the thigh armor; this is a stupid mistake, because the soft parts will soon be pushed upward and the cicatrix inevitably irritated. It is indispensable, if we wish to avoid these accidents, to envelop the stump in a triangular piece of linen, the face angle of which should be passed through the fenestrum made on the thigh armor, and it is drawn on in such a manner as to draw downward the soft

parts within the apparatus. If this measure is not sufficient to prevent the pushing up of the soft parts, we must have recourse to a more radical procedure, the chamois skin drawers extending above the base of the thigh. This device is shown in Fig. 229.

Fig. 228.

Fig. 229.

As many of those who had their legs amputated prefer a wooden leg to a more complicated apparatus, so nearly all the men, belonging to the working class, prefer the thigh armor with the peg leg, for the reason that it gives them a firm support in standing and walking, and by reason moreover of its extreme simplicity. Its principal inconveniences are the same as those of the peg-leg, the painful pulling and irritation of the pelvis by the abdominal belt, notable embarrassment caused by the inflexibility of the peg leg, and insufficiency of the base of support. The procedures which we have indicated in order to palliate these inconveniences, in the wooden leg, are perfectly applicable

here; we may therefore, with the aid of a bolt, permit, for the sitting position only, flexion of the articulations of the hip and knee, or we may also adopt to the apparatus the artificial foot of de Beaufort. Camille Myops presented to the exposition of 1867 a very ingenious thigh armor with a peg leg, which has

Fig. 230.

Fig. 233.

Fig. 231.

Fig. 232.

been described in Gurlt's book, published in Berlin, in 1868. The various parts of this apparatus are shown in Figs. 230, 231, 232, and 233.

The parts represented in the different figures are as follows: Fig. 230, complete apparatus; Fig. 231, padded leather cone in

which the stump is placed; Fig. 232, cut of the lower part of the peg leg; Fig. 233, longitudinal cut of Myops's apparatus. The thigh armor of this artificial limb is composed of a very thin shell of linden wood, presenting at its superior extremity two indentations, *a* and *b*, destined to lodge, the one the buttock, and the other the perineum. The shell *E* is covered with cloth and coated with glue, and afterwards enveloped with leather which contributes to increase its solidity. An iron stem with a movable articulation, starts from the outer side of the thigh armor, in order to support a cushioned belt, from which some leather straps descend to the thigh armor assuring the solidity of the apparatus. Inferiorily, the thigh armor terminates in a hollow peg leg in which the lower extremity, very large, presents a hemispherical cavity resting on a second piece, *G*, with a hemispherical concavity, and which is only attached to the apparatus by some rubber cords. This second piece, *G*, of which Fig. 232 represents a longitudinal cut, is surrounded by a leather case, *e e*, which is very large, in order to present a good base of support, resting directly on the earth; its lower part is covered with a very strong sole, *f*; at the centre of this piece there will be found a canal, *d d*, which terminates in a central cavity. This canal affords a passage to the cord, *h h* (Fig. 233), which, descending in the peg leg, *k k*, cross each other at *i*, and unite in the central cavity of the lower piece, where they are fastened with a screw. The object of this mechanism is easily comprehended. When the maimed throws his foot forward in order to take a step, the ordinary peg leg touches the earth only on its borders and consequently slips with the greatest facility. In Myops's peg leg the sole, *f*, always firmly adheres over its entire surface to the earth, whilst the peg leg properly so called turns on the hemisphere which presents the superior face of the part *G* (Fig. 231). It is a mechanism exactly similar to that which was applied by Bechard *for a long time, to the lower extremity of a crutch*. Myops has also designed a thigh armor in which the interior is not padded, although its upper border is well cushioned; the maimed places his stump in an accurately fitting leather cone (Fig. 231), everything being arranged in such a manner as not to press on the cicatrix; and

an opening is made at the lower part of the cone to permit the air to escape while introducing the stump.

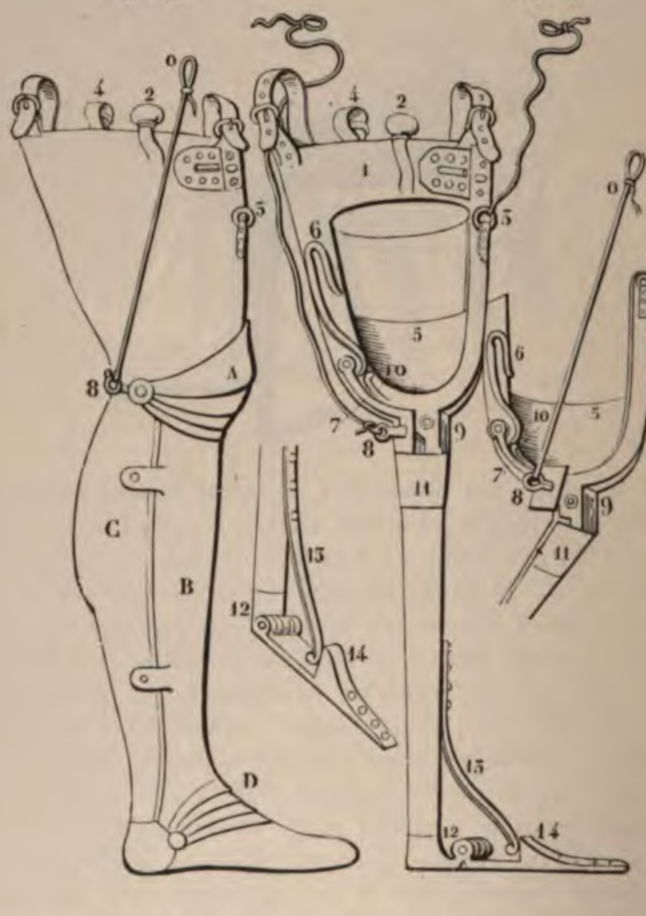
The English frequently employ an articulated peg leg, which is at all times simple, elegant, and convenient. We borrow a description of it from Bigg's Orthopraxy, London, 1865. This apparatus, shown in Fig. 234, is composed of a wooden thigh

Fig. 234.

armor in which the upper part, *A*, gives an attachment to a belt which surrounds the pelvis, the lower part of the armor is formed of two pieces which are movable on each other at the level of the knee, *B*; its apex terminates by an ordinary peg leg, *C*. A vertical spring, placed at *D*, moved by the patient's hand, permits the complete fixation of the limb for standing or walking. The artificial peg legs which we have already examined do not conceal the deformity, therefore man's ingenuity was taxed for a long time to produce a more complete apparatus, and the rich man's leg by Ambrose Paré was offered as the first example. This important invention is shown in its various parts in Figs. 235 and 236, and the different pieces of which it is composed are described by Ambrose Paré in the following terms: Naked leg (Fig. 236), *O*, the strap by which the ring of the tumbler is pulled to bend the leg. 1. The thigh armor, with the screws and the

holes for the screws to release or compress the thigh. 2. The knob for raising, lowering, or turning the thigh armor. 3. The small ring in front of the thigh employed to raise and direct the leg at will. 4. Two buckles in front and one behind for the purpose of supporting the thigh armor by aid of the straps passing over the patient's shoulder. 5. The

Fig. 235. Fig. 236.



small receptacle within which is placed the stump, extending upward about two inches from the lower end, serving thus

to give beauty and form to the limb. 6. The spring moving the tumbler which locks the leg. 7. The tumbler which holds the wooden peg extended and locked for fear that it might reverse. 8. The ring to which is attached a cord to pull the tumbler, in order to flex the artificial limb, when the patient wishes to be seated on horseback or otherwise. 9. The hinge, placed in front of the knee, permitting flexion and extension of the leg. 10. A small catch to prevent the tumbler from passing outside of the thigh armor, because if it did so the spring would be broken and the man would fall. 11. The iron ferrule in which the wooden leg is inserted. 12. The other ferrule at the bottom of the wooden leg, carrying a hinge on which the foot moves. 13. A spring permitting the anterior portion of the foot to be raised or lowered. 14. A catch which acts on the spring so as to depress the anterior part of the foot when it ought not to be raised.

Having previously called attention to A. Paré's naked artificial limb, it now remains for us to present the clothed and beautified extremity which is shown (Fig. 235), and described as follows: *A*, plates to give a neat appearance to the knee. *B*, an armor to beautify and render natural the appearance of the leg. *C*, the artificial calf representing the form of the natural parts. *D*, plates covering the defects of the ankle. The rich man's leg of Paré has a very perfect mechanism, but it should be remembered that it was not the first attempt at the construction of an artificial limb; nevertheless it is heavy and complicated, so that it only exists in science with its historic title.

At the present time, we employ instruments of extreme lightness; we shall be very brief in their description, because they are similar to those which we have already described as suitable for amputations of the leg; they differ especially from these in this, that the thigh armor terminates at the level of the knee-joint in a hollow cone pierced with a fenestrum, which, like the thigh armor with the peg leg, allows the passage of a piece of linen which surrounds the stump. The articulation of the knee is generally eccentric; sometimes certain modifications are sustained to facilitate the extension or limit the flexion; we will return to this hereafter. The thigh armor ought, in all cases, to

extend upward to the level of the coxo-femoral articulation, in order to take a point of support from the surrounding parts. The taking of the point of support from the cone of the thigh should be a serious question; the apparatus is certain to push the soft parts upward and irritate the cicatrix; moreover, we have already called attention to the fact that the apparatus pretending to take its support from the thigh cannot be aided by an additional support on the lower border of the patella, and the tuberosities of the tibia which no longer exist. With marked skill they have succeeded, in the mean time, in making some artificial limbs which do not extend up to the ischium, but it is an essentially false principle; not only should the artificial limb extend upward as far as the ischium, but still, in order that it may not be necessary to fasten them firmly, it is necessary that they should be further aided by the addition of an abdominal band sustained by a splint; this splint should have a movable joint in order not to embarrass the play of the coxo-femoral articulation. These principles are embodied in the artificial limb of Robert and Collin which is provided with hollow steel splints and shown in Fig. 237.

Robert and Collin have diminished the weight of the apparatus by hollowing out all the steel splints which enter its composition; they have accomplished this result, without impairing their strength, by turning the steel plate in such a manner that its central part makes an external projection, whilst the lateral parts make an internal projection, as is represented in *B* (Fig. 237). The various artificial limbs of Martin, Bechard, Mathieu, de Beaufort, and Palmer described while considering the prosthesis following amputations of the leg, are perfectly applicable here; each one, with our advice, should be extended up to the ischium. We still prefer the systems of Bly and Myops, because of the perfection of the tibio-tarsal articulation. De Beaufort's leg permits the patient to walk only when it is retained in the condition of absolute rigidity; while with all the others he may walk with a stiff artificial limb, or with one which is flexible at the knee. In order to obtain this latter result, it is sufficient to throw the centre of the articulation of the knee behind the axis

of the limb; in a word, it is sufficient to have recourse to the eccentric position. We have for a very long time insisted on this mechanism, and on a system by which walking may be accomplished anatomically, without the muscular intervention, and

Fig. 237.

Fig. 238.

return to it now. If it is desired to arrest completely the action of the knee in walking and standing, it will be sufficient to place a bolt, *D*, on the femoral splint, which should fit accurately into a mortise placed on the top of the tibial splint. This apparatus is shown in Fig. 238.

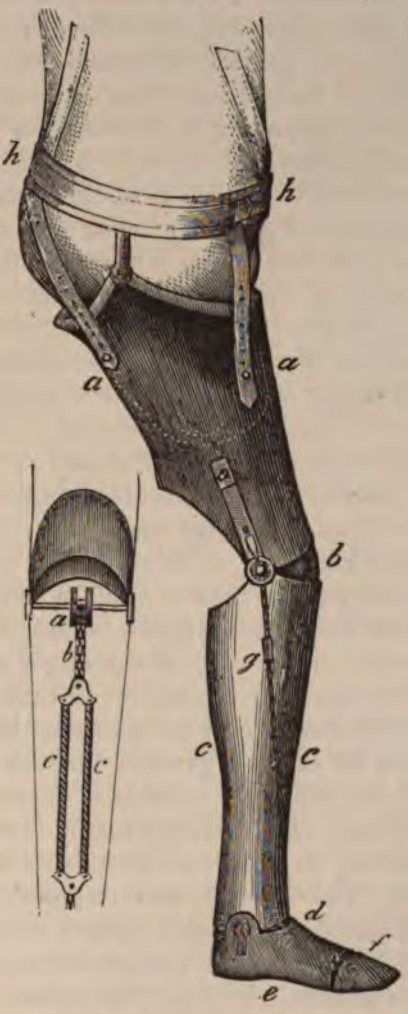
Provided with this bolt, the artificial limb can only be flexed by the express will of the invalid, because the bolt can only be

drawn from the mortise by a movement of the hand. There should be placed behind the bolt a small spring to act constantly on it, not only to prevent it from dropping, but also to compel it to re-enter spontaneously the mortise whenever the maimed rises to the standing position after having been seated. This arrangement is indispensable, because the maimed might forget that he had destroyed the rigidity of his artificial limb, and as a result expose himself to a fall. We can arrange the length of the bolt and a catch point movable by the hand, and retaining it when raised. This arrangement is useful to those maimed who are not yet accustomed to work their apparatus; it enables them to render flexible the articulation of the knee, when they are within the reach of a point of support, and immovable under the opposite circumstances; little by little, they throw aside entirely the use of the bolt. When the maimed utilizes the limbs with a flexible knee while walking, they experience, as we have already indicated in our description of those which are suitable for amputation at the point of election, a certain difficulty in projecting the artificial limb rapidly enough; they especially fear that this limb will be too completely flexed, if the foot happens to encounter an obstacle. We must provide ourselves beforehand with mechanisms arranged so as to obviate these two inconveniences. One of the simplest mechanisms to facilitate the projection of the limb consists in a rubber band, which Mathieu has adapted to an apparatus for an amputation of the leg. It is evident that this elastic band, always stretched, tends to draw back the artificial leg, when the weight of the body no longer rests on the apparatus; it consequently facilitates the projection of the leg, and up to a certain point is an obstacle in the way of exaggerated flexion.

Another very ingenious mechanism has been employed for the same purpose by Goldschmidt, of Berlin. Goldschmidt's artificial leg, which is shown in Figs. 239 and 240, is composed of a smoothly padded thigh armor which extends upward as high as the ischium. The firmness of this thigh armor is secured by a belt, *h h*, which is united to the splint by a hinge. Inferiorily the thigh armor is articulated with the leg, *c c*, by a

hinge, *b*. The leg portion is, in its turn, joined to the foot, *e*, by an articulation, *d*, possessing an elastic mobility due to the

Fig. 239.



presence of two spiral springs, deeply situated in front and behind. In the anterior portion of the foot is a hinge, *f*, which takes the place of the metatarso-phalangeal articulation, which

is also made elastic by a spiral spring deeply situated. The toes of the foot are slightly raised to prevent them from striking against the ground when the foot is carried forward. Goldschmidt's limb in its general appearance resembles the limbs which we have already described, but differs in its mechanism for the knee, which will be better understood after an examination of Fig. 239. A stem passes from one side to the other of this articulation; supporting in its centre, a pulley, *a*, to which is attached an articulated chain, *b*. This chain terminates in two hooks, from each of which is suspended a spiral spring, which is attached inferiorily to the anterior wall of the leg. The direction of the chain and spring is shown by the line, *g* (Fig. 239). In the flexion of the knee, this turns on its axis with the pulley, *a*; as a result the chain, *b*, is unrolled and the springs are extended. Whenever the foot leaves the ground, and when abandoned to its proper movement, the articulation of the knee is extended by the elasticity of the springs. The action of a screw, placed on a level with the articulation of the knee, renders this joint immovable in extension or in flexion at a right angle, in such a manner that the maimed may, at will, walk with a stiff or flexible limb. If the screw is not completely tightened, the knee remains flexible within a certain limit; this arrangement is the more advantageous, because it prevents the exaggerated flexion of the leg on the thigh, when the foot encounters an obstacle, and it attains this object without embarrassing the patient's walk. It is not necessary, in fact, in order that the walk may be easy and graceful, that the articulation of the knee should be sufficiently movable to permit flexion to a right angle, and for a much stronger reason to an acute angle. It suffices for the leg to make with the thigh a slightly obtuse angle backward. The maimed who employs Goldschmidt's apparatus ought therefore to merely tighten the articulation of the knee at the joint permitting this degree of flexion; when the patient desires to be seated, he turns the screw in such a manner as to permit flexion only to a right angle.

An artificial limb which has an articulation of the knee constructed according to the views of Goldschmidt, and a tibio-

tarsal articulation conforming to Bly's system, possesses, we think, the highest type of perfection. We have remarked that Goldschmidt's artificial leg may be employed for amputations at the point of election; it is sufficient to arrange the springs in such a manner that they may play in the grooves made in the lateral walls of the apparatus instead of playing in its interior. If it is desired merely to limit the flexion of the leg to a predetermined degree, without seeking to facilitate its projection forward, we may have recourse to different mechanisms, among others to that of Bly, represented in Fig. 240, but it is not necessary to employ any springs. Charrière has solved the problem by placing along the eccentric splints a screw similar to that which we have represented in Fig. 238, and by making the mortise a little larger than the bolt; the play of this bolt in the mortise secures certain movements of flexion which cannot, in any case, surpass the limits determined beforehand. The simplicity of this invention does away with all the mechanisms; but, unfortunately, nothing can be arranged to facilitate the projection of the limb, to accelerate the pendulum movement. The question now before us is, What apparatus shall we choose? The choice is between the apparatus in which the artificial limb is rigidly extended while the patient is walking, and that in which it is flexible. Theoretically, the latter, when the projection of the leg is facilitated, when exaggerated flexion is rendered impossible, offers as much stability as the others, and renders walking easier. In practice, a large number of the maimed prefer the rigid apparatus, because they dare not try the former. The rigid apparatus enables the patient to walk immediately, whilst the other requires some practice. The habit of walking is easily acquired with Goldschmidt's apparatus, where the motion may be so limited as to suit the fancy of the patient. Before concluding the study of the prosthesis in amputations of the

Fig. 240

thigh, we wish to remark that all the preceding artificial limbs require a stump of a certain length; if the amputations were made through the lower part of the trochanters, they would evidently be inapplicable. The best apparatus invented for this particular case was presented by Lebellequie, and is shown in Figs. 241 and 242.

Fig. 241.

Fig. 242.

This apparatus was applied by Chassaignac in a case where the stump was only eight centimetres in length; consequently it could not penetrate deep enough into the thigh armor in order not to be displaced by the least movement. In order to remedy this difficulty, Lebellequie determined to clothe the maimed with chamois-skin drawers (Fig. 241), the extremity of the drawers, *B*, on the maimed side terminated by a long strap, *C*. The stump having been thus prepared is placed in the thigh

armor (Fig. 242), the strap having been drawn as tightly as possible, is fastened to the bottom of the fenestrum in the armor of the thigh. By this artifice the apparatus is united to the drawers, and consequently to the stump itself; it is not subject to any displacement. Debout has remarked, however, that the fenestrum in the thigh armor should be placed in front, because in pulling the strap in the direction indicated by the figure gives to the stump a strong tendency to push forward, when it would rest on the anterior border of the apparatus in the movements of flexion. It is evident that instead of adopting the peg leg to the inferior extremity of the thigh armor, there could be employed an artificial limb representing the natural form.

Coxo-Femoral Disarticulation.

During a long time it was thought that the wounded who had submitted to this operation, which is of very recent date, would only be able to walk by the aid of crutches. Vidal, of Cassis, still puts forth this opinion in the fourth edition of his *Traité de Pathologie externe et de Médecine operatoire.* This was a deplorable view, because, besides the trouble which they occasion, the crutches may give rise to very grave lesions, when they are employed to support the whole weight of the body while walking. The vessels and nerves which traverse the axillary region are compressed by the cross piece at the upper end of the crutch; and from this atrophy sometimes results, and even paralysis of the superior extremity. These accidents have led surgeons to seek for more desirable means. At the Hôtel des Invalides they have employed an apparatus for a long time for a patient called Rembourg, for whom Sedillot disarticulated the thigh in 1840. This apparatus and a modification of it by Charrière are shown in Figs. 243 and 244.

This apparatus, the description of which we borrow from Debout, is composed of a hollow wooden cone, *C*, terminating below by the peg leg, *P*, and above by the pallet, *E*. There are fastened to this pallet two leather straps, *MN*, which are buckled about the loins, after having passed through the holes made in

a large cushioned leather belt which surrounds the lower part of the chest. The anterior part of the inferior strap, *N*, passes also into a third strap, *O*, which is fastened to the wooden cone of the apparatus. Finally, a handle *D*, serving to move the

Fig 243.

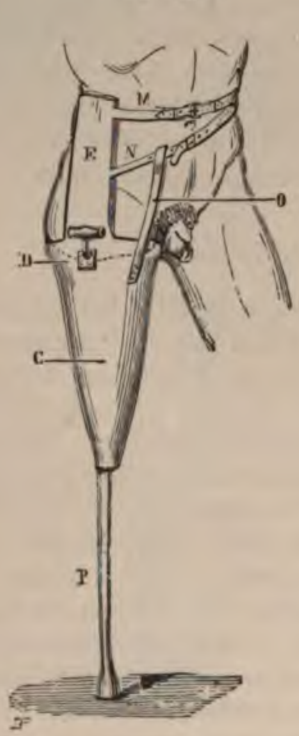


Fig. 244.

limb, *P*, is placed on the outer side of the thigh and within reach of the hand. This apparatus is only in the main, that of the thigh armor employed in cases of amputation of the thigh, with this difference, that the hollow cone is replaced by one with a slighter excavation; the leather straps which are attached to the pelvis are not sufficient to keep it firmly fixed, therefore the maimed can only utilize it in this condition by being endowed with very great skill. This apparatus is always disarranged in the sitting

position, and consequently the maimed is obliged to readjust it whenever he arises. Charrière has tried for the coxo-femoral disarticulation an apparatus which fulfils better the principal indications than the preceding, but without being entirely satisfactory. This apparatus will be better understood by examining Fig. 244. A grooved and cushioned piece of leather, *G*, moulded accurately to the stump is attached to the pelvis by two leather straps; it is articulated inferiorily at *A*, to an iron ring, *R*, which itself is attached to a long wooden peg, *T*. This means of prosthesis affords more stability than the wooden cone described by Debout, but its use is very fatiguing, and the patient at the *Hôtel des Invalides* greatly prefers the cone apparatus.

The credit of having first laid down the principles which ought to guide the prosthesis of coxo-femoral disarticulations belongs to the Inspector of the French Navy, M. Foulliay, and as these principles should be presented accurately to surgeons and mechanics, we will therefore translate them from the original text. M. Foulliay says: "We cannot direct our thoughts to the anatomical structure of the lower parts of our body without being convinced that the sitting posture engaged the attention of Providence. The position and size of the tuberosity of the ischium, the thickness and the elasticity of the tissues which cover it, the very great density of the skin render this region very appropriate for the support of the weight of the body. It is equally well adapted to transmit it, and a proper regard for this governs the prosthesis, and should also regulate the operative procedure. Nevertheless, however, fortunately arranged the tuberosity of the ischium seems to be, it forms, in the case of the loss of a lower extremity, a very narrow base of support, either for standing or for walking; it is not sufficently prominent to allow us to attach the artificial limb; it is immovable, and consequently incapable of communicating movement; no natural intermediate substance does effectually deaden the shock caused by the artificial limb coming in contact with the ground.

"Before we have completely remedied these different inconveniences, it will be in vain that we flatter ourselves with com-

plete success. In the normal condition the lower extremities serve as a counterbalance for the upper part of the body and broaden its seat. The coxo-femoral disarticulation having been performed on one side, the body ceases to be balanced, and rests merely on a single bony protuberance; large it is true, but convex and merely touching the plane of support by a single point; and a simple keel adjusted to this tuberosity would leave the patient in continual vacillation. Nature has admirably arranged that the weight of the body pass in a straight and central line, because there are distributed about it contractile agents which maintain the equilibrium; but we are deprived of these remarkable agents, and in order to supply the mechanism of the natural limb, it is necessary that the means of prosthesis embrace the whole space occupied by them. Now, the space required for the attachment of the artificial limb is not reduced to the cylindrical circumference of the thigh, it embraces the surface of the pelvis to which are inserted the muscles which, while standing or walking, assure a normal harmony between the pelvic bones and the femur." The application of the principles expressed in the above are embodied in an apparatus invented by M. Foulliay which is represented in Fig. 245.

He further says: "In accordance with these views we have enlarged and rendered oval the pelvic armor, *B;* we have given to it eighteen and one-half centimetres from before backward, and sixteen and one-half from within outward. The pelvic armor, which has raised on its external part a bulwark, is moulded to the iliac and gluteal regions, in such a manner that nine-tenths of the corresponding half of the pelvis is exactly included within its embrace. Metal rods, destined to prolong the limb, are fastened to the extremities of the transverse diameter of the pelvic armor, they descend, while at the same time approaching each other, and communicate to the whole of the piece the appearance of an inverted cone, which is the form of the natural limb, without the foot. The pelvic armor which is adapted to the pelvis is strongly fastened down by five leather straps, the first two perform the office of a belt by passing below the crest of the ilium; two others co-operate in the same object, but one is placed higher

on the thorax; the fifth descends from the axilla in order to be buckled to the middle part of the superior border of the bulwark.

Fig. 245.

"We have not hesitated to sacrifice lightness for solidity; the frame of the apparatus is of metal, and we have made it strong enough to resist for a long time the violent shocks which it incessantly receives in walking. In the mean time the total weight is less than nine pounds Troy, which does not represent one-half

the weight of the natural limb. Where are we to find the motor power? We try in vain to borrow it from the os innominatum, which is itself immovable. We have sought it in the articulations of the vertebræ, in the dorso-lumbar region, and in the powerful muscles which pass from the thorax to the pelvis. It was, therefore, necessary to fasten one apparatus to the thorax, and especially over the shoulder, by means of a double corset, *C.* The result has been more satisfactory than we anticipated. By the combined muscular contractions, and by the aid of a sort of nodding movement of the chest, our patient throws forward the artificial limb, and transports the weight of the body with much ease and rapidity. He required no staff on a smooth plane, and with the aid of a cane, he completed without resting, a journey of two miles in the mountainous regions of the suburbs of Brest. I attribute the activity and energy of the progression on the city pavement to the precautions which we have taken to deaden the shocks occasioned by striking the earth. When the peg strikes the earth, the percussion wave does not rise directly by a single stem to the axis of the ischium, it is divided and propagated along the metallic rods, where it is weakened by contact with two layers of thick leather. Having reached the upper part of the thigh, it is dissipated by a right angle, a mechanism similar to that of the natural organization; a part of it is dispersed on the rampart of the pelvic armor, while the balance is transmitted to the armor itself by its structure which absorbs its last vibration. Two articulations, *H D*, are arranged at the knee, and at the level of the cotyloid cavity, enabling the patient to be seated, to fold up his limb, and to conveniently assume the attitude of repose."

Foulliay's artificial leg has been used a great number of times and with the greatest success. M. Danve has reported to the Surgical Society on two invalids, who by its aid could walk admirably. A young Irishman, whose history Debout gives, employed it very satisfactorily, and in this case the fact is the more remarkable since the whole right limb had been lost and the left had been reduced to a stump about one-half the length of the femur (it was here employed in a case of ectromeles). An

apparatus has been designed by Charrière, constructed on the principles enunciated by M. Foulliay, which the reader is enabled to appreciate after having read the preceding passages, but will be more easily comprehended by a study of Fig. 246.

Fig. 246.

Here Charrière has made a fortunate modification of Foulliay's apparatus: an artificial foot masks more completely the deformity than the peg leg of the primitive apparatus: the principal modification consists in the addition of the leather strap which passes from the foot to the shoulder of the opposite side; consequently the movements of the shoulder are made to contribute to walking. Doctor Simpson says that a young Irish lord, supplied with these two artificial limbs, has become an admirable cavalier. The apparatus designed by Foulliay, excellent in principle, nevertheless presents a few imperfections in the details which Prof. Arland of the Naval School of Medicine has been able to remedy. These inconveniences are, first, the presence of the waistcoat to which are fastened the attachment straps; this waistcoat impedes movements and causes an insupportable heat during summer time; second, the pelvic armor of Foulliay's apparatus is much too thick in its lower part, the natural result of which is that the coxo-femoral articulation of the artificial limb is situated much lower than that of the healthy side—a very serious impediment in sitting; third, the inferior border of the pelvic

armor comes too near to the inter-gluteal line, so that the maimed is compelled to lay aside his apparatus whenever he goes to the water-closet; fourth, the artificial limb is too heavy. Prof. Arland has remedied these inconveniences by having the following artificial limb constructed by Aubert, a truss maker at Toulon, and which may be better understood by examining Fig. 247.

Fig. 247.

Fig. 248.

In this apparatus the large waistcoat is replaced by a belt, *A*, of fifteen centimetres in width, fastened in front by three buckles

and supplied by two subscapular suspenders, and with two inferior oblique leather straps, *C*. The steel or pelvic armor, *D*, made on a plaster mould, is so thin in its inferior part, that there is no difference in the height on the injured or healthy sides, except a slight thickness of leather below the ischium, consequently the sitting posture can be assumed with readiness. The intergluteal line is arranged in such a manner as to permit defecation. Finally, Arland's limb is more than eight ounces lighter than that of Foulliay. It should be understood, in this apparatus as in that of Foulliay, the coxo-femoral articulation, *E*, and the tibio-femoral, *G*, should only be flexed for the sitting position. Some bolts moved by the band secure perfect immobility for walking. Robert and Collin have made some alterations in the apparatus of Foulliay rendering it as perfect as possible. In the apparatus of Robert and Collin, which is represented in Figs. 248, and 249, we are enabled to study this artificial limb in the standing and sitting position, and here it should be further observed that the pelvic armor is not limited to merely surrounding the patient's hip, but it embraces the whole circumference of the pelvis, on which it is accurately moulded; on the maimed side, it covers completely the stump, on the opposite side it occupies the space between the crest of the ilium and a transverse line situated about five centimetres above the trochanter major in such a manner as not to interfere with the movements of the healthy leg. The internal posterior border of the pelvic armor is arranged in such a manner as to leave the arms perfectly free. That portion of the pelvic armor situated beneath the stump is as thin as in Arland's apparatus, in order that the two ischia may sensibly rest on the same line, a condition indispensable to the sitting position. The thigh armor, the leg, and the artificial foot, are exactly similar to those which are employed for amputations of the thigh, but the articulation which unites the thigh to the pelvic armor deserves attention. The external femoral splint is only articulated by a bolt at *A*, with a splint placed on the outer side of the pelvic armor; the internal femoral splint terminates at the level of the pelvic armor without being attached

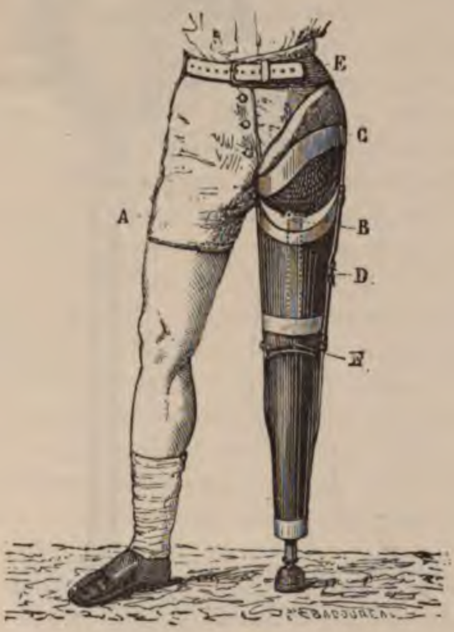
to it; this arrangement was primarily necessary because an internal articulation made a projection, interfering with the sitting posture. It was secondarily necessary, since the weight of the body was not transmitted uniformly through the external articu-

Fig. 249.

lation, *A*; the standing was unstable; this difficulty was remedied by uniting the external and internal splints with a transverse metallic rod, occupying the upper part of the thigh armor; and in the centre of the metallic rod is a vertical slide moving during flexion and extension in a groove extending from below upward on the lower part of the pelvic armor. When the artificial limb is in extension, the weight of the body rests, by the intervention of the slide, on the middle of the bolt which unites the two splints, and consequently on the axis of the artificial limb. We have yet to remark that the articulation, *A*, is placed exactly at the

level of the line passing through the apex of the head of the femur of the sound side; this arrangement is one of extreme importance, because if the articulation was placed lower, the thigh armor, in flexion, would occupy a plane further back than the pelvic armor, and consequently the maimed could only sit on the edge of his seat in a very uncomfortable position. It may now be said in conclusion, that Robert and Collin's apparatus assures a stability as complete as possible for standing, walking, or sitting. It should be understood, that the artificial limb is always rigid for walking, which is accomplished by undulatory movements of the trunk, as in Foulliay's apparatus, and is only

Fig. 250.

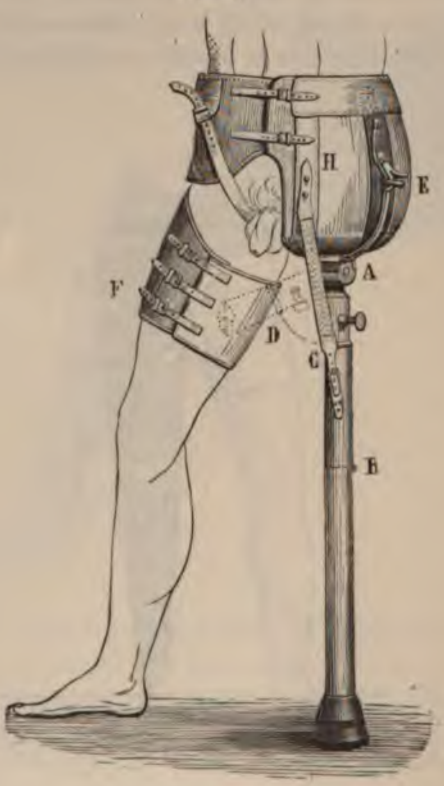


flexed for the sitting posture. This flexion is accomplished by the two bolts, *D* and *D*, running on the femoral splint, and these bolts are arranged in such a manner as to act simultaneously. Lebellequie has made an apparatus under the direction of

Richet, which is at the same time both light and stable, by making the maimed to wear drawers such as are represented in Fig. 242. This artificial limb is represented in the preceding illustration, Fig. 250.

In this new arrangement the pelvic armor is pierced at *B*, by an orifice which gives passage to a strap from the drawers which descends through the thigh armor and is attached by a strong

Fig. 251.



buckle to a roll, itself fastened to a metal cross piece, which is riveted transversely on the inner side of the articulation of the knee. Thanks to this proceeding, the apparatus only acts with the drawers, and consequently with the body itself. Mathieu

has presented, on his part, a new apparatus which seems to be well arranged, but has not, as have the preceding, the sanction of experience. It is shown in Fig. 251.

The principal point of support is taken in this apparatus from the tuberosity of the ischium as in the models designed on the information of Foulliay, but the pelvic armor, made more complete, embraces the whole pelvis. Furthermore, a thigh armor, *F*, is fastened to the pelvic armor by a metal rod, broken and articulated at the level of the coxo-femoral articulation, surrounds the base of the sound limb; and this thigh armor secures the stability of the apparatus and the harmony of motion between the legs. Below the pelvic armor is a peg leg for the support of the weight of the body, which is fastened to the armor by a hinge, *A*, which permits flexion for sitting, and complete extension for the upright position. For the purpose of working the peg leg, *B*, is not fastened in a perfectly perpendicular position; it is slightly inclined from above downward and from behind forward. These different directions are given to the peg leg by means of a spring, *C*, movable with the hand and placed near to the hinge. This spring is arranged in such a manner that the peg leg possesses a slight degree of mobility while walking, in order that the elastic strap placed at *D* may be able to raise it slightly, and thus to assist in walking. We believe the apparatus of Mathieu possesses very little practical value. Nevertheless we ought to give due credit for the opening which this ingenious designer has made at the point of the emergence of the great sciatic nerve; it is a brilliant idea, because it is well known that pressure on this nerve by the apparatus frequently produces such intolerable pain that we are absolutely compelled to abandon all means of prosthesis. Dauvé, while exhibiting to the surgical society some diseased pieces of this nerve received from the *Hôtel des Invalides*, touched with the finger the cause of this pain; and concluded his remarks with a most rational proposition, "the exsection of the nerve during the performance of the operation." In view of the prosthesis this resection ought to be considered as indispensable.

Crutches.

However perfected may be the artificial limbs for the prosthesis of the lower extremities, patients sometimes feel the need of crutches. Crutches are so well known that it is useless for us to give a description of them; but we are constrained to point out some means by the aid of which we may render less painful the pressure of the soft parts of the axilla, and by the assistance of which we may secure greater stability of the lower extremity. The pressure exercised on the axillæ by the leather cushions, which are commonly filled with hair or wool, and placed on the superior end of the crutch frequently becomes painful, because the hair or wool soon becomes compressed, and is then very hard. Galante has remedied this defect as far as possible by substituting for the former air cushions. This invention and also the inferior extremity of the ordinary crutch is shown in Figs. 252 and 253.

Fig. 252.

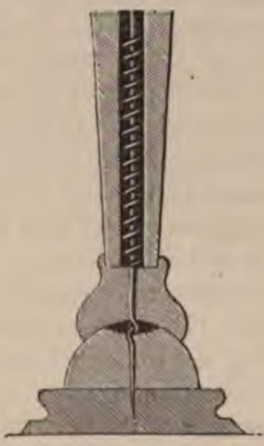
Fig. 253.

These rubber cushions have a slightly concave surface above, and are slightly convex below when they are fitted to the transverse piece of wood on the upper end of the crutch; they present on each side, in their whole length, two wings or appendages which are formed of vulcanized rubber supplied with some non-elastic tissue, while the nails which maintain the cushions in their places are driven through these appendages.

A rubber tube two or three inches in length enables the patient to introduce air or water into the cushion so that he may graduate for himself the degree of elasticity which his experience may dictate. The lower end of the ordinary crutch is merely an extremity of a wooden peg, the edges of which, during the movements of walking, only come in contact with the earth, and is therefore very liable to slip. The crutches of Galante and Bechard have not this grave defect. Galante, placed on the lower end of the crutch a small wooden ball which was introduced into a thimble of vulcanized rubber; by its adherence to the earth and by its elasticity, the rubber assured stability in walking and likewise contributed to lessen the severity of the pressure in the axilla. Figs. 254 and 255 represent the various parts of Bechard's crutch.

Fig. 254.

Fig. 255.



It has been more than twenty years since the senior Bechard proposed to make the peg of the crutch in two parts *A* and *B*. The part, *A*, hollowed by a canal terminates below the concave enlargement, *C*; the part, *B*, represents the half of a sphere, the flat surface of which rests on the ground, whilst its convex surface remains constantly in contact with the concave enlargement, *C*. A strong spiral spring contained in the canal, *A*, and

inverted in the centre of the hemisphere, *B*, secures the apposition of the parts. We will remark in passing that Bechard's ingenious device undoubtedly served as a model for Myops in his construction of a peg leg. We will also add what is still more important that this contrivance may perhaps replace the mechanism of Bly and Myops in the tibio-tarsal articulation.

Measurement Required for the Construction of Artificial Limbs for the Lower Extremities.

It is necessary to measure for the ordinary wooden or peg leg: 1. the length from the perineum to the centre of the knee; 2. the length from the centre of the knee to the extremity of the stump; 3. the circumference of the middle and the lower part of the thigh; 4. the circumference of the knee and the extremity of the stump; 5. the distance from the knee to the ground. It is well at the same time to take the following measurements on the sound limb: 1. the length from the middle of the knee to the ground; 2. the length from the perineum to the ground. It is necessary to measure for the thigh armor of the peg leg: 1. the distance from the perineum to the end of the stump; 2. the circumference of the thigh on a level with the perineum; 3. the circumference of the end of the stump. It is likewise well to measure the healthy limb to determine the length from the perineum to the ground. The measurements for artificial limbs other than the peg leg, are somewhat complicated, and vary with the different methods of amputation. In the case of a tibio-tarsal or partial amputation of the foot, the apparatus can only be conveniently made from a plaster mould. This mould is less necessary in cases of amputation through the middle of the thigh as well as in the leg, since measurements of the stump and the healthy limb may in a certain degree supply its place. The measurements demanded by Charrière are the following, and should be taken of the healthy and crippled limbs.

Amputation of the Leg.—The measurements on the side of the amputation are: 1. the length from the perineum to the

centre of the knee; 2. the length from the centre of the knee to the end of the stump; 3. the circumference of the thigh at the level of the perineum; 4. the circumference in the middle and at the lower end of the thigh; 5. the circumference at the knee; 6. the circumference of the end of the stump. The measurements to be taken on the healthy limb are: 1. the length from the perineum to the earth, and from the centre of the knee to the same point; 2. the circumference of the calf; 3. the circumference of the malleoli.

Amputation of the Thigh.—The measurements to be taken on the side of the amputation are: the length from the perineum to the end of the stump, and the circumference of the thigh on a level with the plane of the perineum, and at the end of the stump. The measurements on the healthy side are the same as those required in cases of amputation of the leg, with the addition of the circumference of the body. The apparatus for coxo-femoral disarticulation can only be conveniently made from the plaster moulds.

CHAPTER IX.

THE CAUSES, PECULIARITIES, AND TREATMENT OF SHOCK. ACCIDENTAL HEMORRHAGE AND ITS MANAGEMENT. TRAUMATIC DELIRIUM. AN EXPERIMENTAL INQUIRY INTO THE ETIOLOGY AND DISTINCTIVE PECULIARITIES OF TRAUMATIC FEVER. SECONDARY HEMORRHAGE, CAUSES AND TREATMENT.

PRIOR to the present century there had been very little or nothing written on the subject of shock in the English language; although Ambrose Paré tells us that while the King of France was besieging Turin, in 1536, the wounded were frequently overtaken with "an awful trembling and disorder of the nervous system, the bravest cannot resist it, and the most acute physiologists cannot tell whether it is a disorder of the body or a tumult of the mind," and he afterwards added: "What indeed could more resemble the bite of a serpent or some poisoned wound than an instant affection of all the body, a trembling and an unaccountable sinking within, yellowness of the face, paleness of the extremities, a failing of the pulse, and a livid wound from which no blood is discharged." John Bell said, in 1807, "When your wounded patient is first brought to you he is in great confusion, there is a tremor, a tonic stiffness, or almost a convulsion of the whole frame; there is coldness, fainting, and nervous affection; but it is merely a nervous affection, and you should treat it as such. You may expect it to subside in time, and therefore should give some warm cordial and large opiates to quiet the commotion; this is no time for bleeding, whatever the nature of the wound may be. If the stupor continue you should give cordial draughts and wine."[1]

In 1826 Benjamin Travers published the first edition of his

[1] "Discourse on the Nature and Care of Wounds," vol. i. p. 182.

celebrated work on "Constitutional Irritation," which is even now cited as an authority on the subject of shock. The scope and character of this work may be readily inferred from the following language employed in his preface to this edition: "My object therefore in undertaking this inquiry was to ascertain with more precision the morbid state indicated by the term 'constitutional irritation,' to investigate the causes most productive of that state, the phenomena by which it is manifested, and the laws by which it is governed; and from the comprehensive view thus obtained to derive, if possible, some permanent pathological characters, which might serve as a guide to more correct notions of its nature, and more scientific principles for its treatment." Dr. Copland in his *Medical Dictionary*, a publication which was commenced in 1840, gives an article of some length on shock. He says: "Although the effects of shock have been recognized by most observing persons, even by the uneducated, yet they have received extremely little attention from medical men; they have not been noticed either in medical or surgical writings, excepting very casually in some surgical works; and I believe that they are now treated of for the first time in a systematic medical work."[1] The attention of the medical profession having been fully directed to the subject of shock by the publication of this medical dictionary, we find that every systematic work on surgery now gives more or less space to the consideration of this topic. The profession is, however, very much annoyed by the multiplicity of names which are employed to indicate this morbid condition.

Dunglison, in his *Medical Dictionary*, cites Copland, and employs the following terms: "Shock, nervous, vital shock, vital depression, nervous depression, fatal sinking, sudden or instantaneous depression of organic, nervous, or vital power, often with more or less perturbation of body and mind, passing either into reaction or into fatal sinking, occasioned by the nature, severity, or extent of injury, or by an overwhelming moral calamity." Erichsen says: "Shock consists in a dis-

[1] Copland, Medical Dictionary, vol. iii. part 2, p. 858.

turbance of the functions of the nervous system, whereby the harmony of action of the great organs becomes deranged."

Druitt, in the first chapter of *The Principles and Practice of Modern Surgery*, says: "As the most proper commencement of a systematic treatise on surgery, we shall begin by describing a state commonly known as *prostration*, or *collapse*, or *shock to nervous system*, by which terms we signify that general depression of the powers and actions of life, which immediately follows any severe injury, such as a compound fracture or gunshot wound." Travers designates this morbid condition, "constitutional irritation," McClellan "insidious shock," Sir A. Cooper "general irritation," Prof. Willard Parker "sudden vital depression," and Dr. Otis "nervous anxiety."

Authors still find it very difficult, if not impossible to formulate a satisfactory definition; one which is sufficiently precise and at the same time so comprehensive as to embrace all the phenomena which belong to this morbid state. The author of this work believes that the following definition possesses some comparative merit, although it unquestionably contains many defects. We will, therefore, venture to assert that shock is a morbid condition arising from an impression made upon the nervous system, whereby the normal physiological action of the vital organs may be either arrested or lowered, but is always deranged.

Etiology.—Shock may be the result of mental impressions or physical injuries, but it is commonly caused by the combined action of both these agencies. Mr. Erichsen has very justly observed that, "In persons of a very timid character, or of great nervous susceptibility—those who are liable to the occurrence of syncope—more especially in females and children, a very trivial injury may produce an extreme degree of shock to the nervous system; indeed, the mere apprehension of injury may, without the occurrence of any physical lesion, give rise to all the phenomena of shock in its most intense degree. People have been actually frightened to death without any injury having been inflicted upon them. The state of mind at the time of the receipt of the injury influences materially its effects on the nervous system. If the patient be anxiously watching for

the infliction of a wound, as waiting for the first incision in a surgical operation, all the attention is concentrated upon the coming pain; it is severely felt, and the consequent shock to the system is unusually great. If, on the other hand, the attention be diverted—if, as in the hour of battle, the feelings be roused to the highest pitch, and the mind in a state of intense excitement—a severe injury may be inflicted, and the patient may be entirely unconscious of it, feeling no pain, and experiencing no shock, perhaps not knowing that he is wounded till he sees his own blood. The severity of shock is in a great measure proportionate to the degree of pain attendant upon an injury. And as sensibility to pain varies greatly in different individuals, so will the attendant shock.

"Furneaux Jordan has pointed out that the functional activity of the nervous system has an important influence in the production of shock. In young children he observes, whose force is developmental rather than nervous or muscular, operations and injuries are better borne than by men in the prime of life, where all organs and functions are subservient to the exercise of nerve force. And the same occurs in persons worn by long-standing local disease, which has lowered the manifestations of vitality without impairing the integrity of the organs essential to life. 'Shock,' he says, 'is essentially a depression or metamorphosis of nerve-force. Where nerve-force is predominant, shock also becomes predominant.'"[1]

The above quotation illustrates the active participation of the mind in the production of shock, and shows it to be a very important factor, but that this morbid condition may be produced by physical injury has been clearly shown by numerous experiments on the lower animals, where there can be no mental impressions. The crushing of their extremities or the application of electricity is followed by the unmistakable symptoms of shock. It has also been observed that the degree and duration of shock are usually proportionate to the extent of the traumatism and the vital importance of the injured parts. It

[1] Science and Art of Surgery, vol. i. p. 197, Amer. edition, 1878.

therefore follows that a gunshot wound involving only certain portions of the soft parts of an extremity, or even the superficial soft parts of the body, may be either entirely, or almost entirely unattended with shock, while a penetrating wound of the abdomen, involving the visceral organs, will produce the *gravest symptoms*, although the extent of the wound is comparatively trivial. Both the extent and character of a traumatism are reflected, in some measure, by the degree of shock which follows the receipt of an injury; and the experienced surgeon always utilizes the knowledge thus obtained in fixing the diagnosis and prognosis. It should, therefore be remembered that the character of shock is dependent on its cause; and consequently this morbid condition may be so evanescent that the reaction will begin within five minutes after the receipt of the injury, followed by a rapid and complete restoration. In other cases the shock may come on quickly, the patient remain several hours without any marked change, and then reaction set in which will restore the invalid to a normal condition during the first day's illness.

In another form of this morbid condition it has been observed, that the shock gradually increases during the first few hours after the injury, and is then followed by a partial or complete reaction. In all these forms death may occur instead of the reaction.

The evanescent variety of shock may be produced by a sharp blow in the epigastric region or by electricity. That form of shock which has been described next in order, commonly supervenes on the receipt of a physical injury, although it is greatly deepened by the mental depression. The peculiar form—the third and last mentioned variety—which is frequently designated as delayed shock, may be occasioned by a gradual hemorrhage, an increasing extravasation of fecal matter into the peritoneal cavity, or some other allied condition.

The *chief variations* in the development of this morbid condition find their essential explanation in the physical and mental states of the patient and the *modus operandi* of the exciting causes. It is therefore well to understand that in every instance of shock the primary impression is made on the nervous sys-

tem, and the secondary on the vascular. Failure of the heart's action is the immediate effect of any sudden and violent impression on the nervous system. The degree and danger of shock in any given case must principally depend on the parts involved in the injury, the character of the force producing the injury, and the resisting power of the patient. It therefore follows that children and the old and infirm bear shock badly. There is also a class, whose ages, if calculated by years, should be regarded as favorable, but who are prematurely old by reason of existing hereditary disease or acquired infirmities, and consequently they suffer severely from shock after the receipt of a slight injury or other trivial causes. Those persons who are suffering from renal, cardiac, or pulmonary diseases, or from any form of constitutional contamination, will unquestionably suffer more severely from shock than they would if these conditions did not exist.

Travers says, when speaking of the excessive use of stimulants, that: "Of all classes of the working community, the draymen and coal-heavers, and the multifarious tribe of gin-drinking laborers of London, are the most unfavorable subjects for severe injuries and sudden attacks of acute disease. A pure stimulus, as that of alcohol, contains little nutriment, and having, when taken in habitual excess, a constant tendency to incapacitate the organs of digestion, impairs and at length destroys appetite. Malt liquor, when taken in such excess as to form the chief support of life, operates in the same way upon the digestive organs; but its stimulus being less potent, as well as its nutrient matter considerable, its effect upon the constitution are less obvious; under ordinary circumstances, perhaps, less injurious. Yet no description of patients fare worse than brewers' servants under the severe casualties to which they are exposed. They struggle with a morbid plethora. The debauchee of high life ranks, in respect of constitutional strength, with the low drunkard of all denominations; and both require a mode of treatment, under severe injuries, the very reverse of that which is adapted to the man who, from his occupation and habits,

labors, when disease overtakes him, under what may be termed a nutrient plethora."[1]

Sexual excess, living in an impure atmosphere, an insufficiency of suitable food, or sedentary habits, lower the vital powers and render the subject of the vice or misfortune less able to bear up under the depressing effects of shock. It should always be remembered, that any complication which lowers the vital powers diminishes the patient's ability to prolong a struggle against shock or other morbid conditions. It has been claimed by some authors that females do not bear shock as well as males, but we are induced to think that the only difference which has ever been observed, in this respect, must be attributed solely to difference in habits, and factors which have been already named in connection with our subject.

Dr. Frederiek James Gant has called attention to a certain idiosyncrasy in his article on shock. He says: "*Constitutional susceptibility* is well marked in the shock of some individuals; but it requires all the experience and judgment which the surgeon can bring to his aid to foresee this peculiarity."[2]

Mr. Hunter says: "I have seen a man die almost immediately upon the loss of a testicle: I have seen convulsions immediately attend the operation for hydrocele, so that I have almost despaired of recovery. . . . . The loss of a limb above the knee is more than many can bear; the cutting for the stone, where it breaks, and may be an hour in extracting, is also more than many can bear."[3] Sir Astley Cooper, Mr. Abernethy, and others, have called attention to certain unusual results arising from comparatively slight injuries, which are most conveniently explained on the basis of existing idiosyncrasies.

We have now reached a point, in our consideration of this subject, when the question may be properly asked, What are the usual terminations of this morbid condition? It may unquestionably terminate in death or reaction. The former ter-

[1] Constitutional Irritation, p. 21 *et seq.*

[2] Science and Practice of Surgery, vol. i. p. 239, Amer. ed. 1878.

[3] Treatise on Blood, Inflammation, and Gunshot Wounds, p. 403, ed. by J. F. Palmer, Phila. 1841.

mination may occur very soon after the receipt of the injury, or it may be delayed several hours; but death in both instances is commonly *caused by cardiac syncope*. Likewise the reaction may be either *prompt* or *delayed*, *complete* or *incomplete;* but, in every instance, the cautious surgeon will carefully study the reactionary changes before he ventures to speak freely of the prognosis.

The symptoms of shock are commonly uniform and differ chiefly only in degree; and consequently the surgeon is enabled to readily diagnose this morbid condition which is always well marked. The more or less complete failure of the heart's action is commonly the first symptom which attracts the surgeon's attention. This failure of function is indicated by a thready, feeble, slow, and, afterward, frequent and occasionally irregular pulse. The surface of the body becomes pallid, the skin cold and clammy, the countenance haggard, and the eye lustreless. The temperature of the body is commonly lowered one or two degrees, the respiration is soft and sighing, there is much muscular prostration, and commonly some cerebral disturbance. These symptoms are generally present in all cases of shock arising from a traumatism, and there may be added occasionally relaxation of the sphincters, involuntary micturition, hiccough, vomiting, convulsions, stupor, and suppression of urine.

Reaction is a natural restorative process which may begin within a few minutes after the receipt of an injury or be delayed several hours; having set in, its progress may be either rapid or slow, and its termination may be complete or incomplete restoration to the normal condition, but in the latter instance death may be expected to follow soon after a relapse. The term reaction simply implies a restoration of, or improvement in, those functions which have been temporarily paralyzed or deranged; and, therefore, it follows that the symptoms in this condition are the reverse of those observed in shock. The circulation is restored to its normal condition, the pulse loses its irregularity and frequency, and regains its force and fulness. With the restoration of the circulation the temperature of the body generally rises a few degrees above the normal healthy

standard, the pallor or lividity of the skin disappears, and the natural color is restored to the lips, cheeks, etc. The respiration becomes normal, and all the marked evidences of prostration disappear, the patient changing readily his position in bed, even assuming the sitting position, while it will be observed that the intellectual faculties have regained their usual activity and clearness.

The older writers on shock were greatly troubled by a supposed excessive reaction, but this danger has been shown by the practice of antiseptic surgery to be *purely imaginary;* since it has been repeatedly demonstrated that a temperature of 105° F. is entirely compatible with the personal comfort of the patient, and likewise free from danger. It is, therefore, thought that the condition which they observed, was not due to the reaction, but to a septic complication, having its origin in a decomposition and absorption of the wound fluids in wounds favorably situated for this process.

The post-mortem appearances of shock are essentially negative, although the distinguished surgeon, Hunter, claimed that the blood in some cases of death from this disease remained fluid; but it has since been shown that this very rarely or never happens. The heart is often full of blood, more particularly the right side, while the whole venous system is somewhat gorged, unless the shock has been attended with severe hemorrhage. The rigor mortis is commonly well marked. It must be confessed that the study of the pathology of shock serves to convince us that death may be caused either by slow or instantaneous impressions on the nervous centres, which leave behind no traces that have yet been recognized by the pathologist.

The treatment of shock may be properly considered under the heads of prophylactic and curative; although the former is only applicable to those cases in which the surgeon seeks to avoid or diminish the depressing effects which generally follow the performance of a surgical operation. It is scarcely necessary to remark here that the prophylactic treatment may be advantageously employed in all those cases in which amputations are made necessary by disease, and likewise in the secondary opera-

tions. Drs. E. T. Easley and Hunter McGuire were the first surgeons to call the attention of the profession to the prophylactic value of the sulphate of quinine in these cases of shock, when administered in doses large enough to produce a moderate degree of cinchonism, prior to the performance of the surgical operation. Considerable time has elapsed since these surgeons directed the attention of the medical profession to this subject, and the opinion expressed by them has been generally confirmed by other observers. Having followed these suggestions in regard to the administration of the sulphate of quinine in these cases, I am now prepared to say from my own experience that it is here a most important prophylactic agent. The dose must be generally regulated by the age and condition of the patient, although I regard fifteen grains as a moderate quantity for an adult, especially in those cases in which there can be only a single dose taken before the performance of an operation. The proper administration of opium is frequently followed by excellent prophylactic effects, and it is generally admitted that it lessens the shock, even when it fails to prevent it. This drug, when administered for its prophylactic action, in cases of anticipated shock, ought to be given two or three hours before the performance of the surgical operation, in order that the nervous centres may be somewhat blunted by its action, and consequently rendered less sensitive to those impressions which commonly produce the morbid condition. There are also other remedies which may occasionally be employed advantageously as prophylactic agents, but I unhesitatingly affirm that quinine and opium possess more value than all other medicines in these cases. The administration of a cathartic at such a time as to secure its complete action about twenty-four hours before the performance of a surgical operation, exerts unquestionably a very favorable prophylactic influence; and the same may also be said in regard to withholding all solid food from the patient for several hours prior to the operative procedure. There can be no reasonable doubt that a comparatively empty state of the alimentary canal is favorable to a free circulation of the blood; and that it also commonly enables our patients

to retain such medicines and food as may be deemed essential to employ, in order to ward off or aid in lessening the shock. It has long been a well-recognized fact, that mental depression is frequently a very important factor in many cases of shock following the performance of capital operations; and it, therefore, becomes necessary that the mind should be fortified as far as possible to meet this emergency. The proper performance of this task requires on the part of the surgeon, who should manage this affair either alone or through the assistance of some discreet person, a thorough knowledge of human nature, and likewise a high degree of tact. By this effort it is sought to encourage the patient, so that he may cheerfully submit to the performance of the operation, and at the same time be brought into a condition of complete resignation. It may consequently become necessary that he should be convinced of the necessity or advantage of the proposed operative procedure. Should the surgeon fail to accomplish his object, he will not unfrequently find in his patient's spiritual adviser a more successful advocate. In other cases it may require the advice of an older brother or some trusted companion, in whose judgment the patient has been accustomed to confide even more than in his own.

Dr. Easley has said on this subject: "When a patient is about to endure some severe trial of fortitude or capital operation, it is evident that the mind should be fortified as far as possible to meet the commotion that must inevitably follow. A few directions in this relation ought to be insisted upon. A frank, open, cheerful demeanor, free from levity on the one hand, or, on the other, moroseness; kindly encouragement, a favorable but fair statement of the outlook, with the assurance of intelligent and honest efforts to help him, will go far toward securing for the subject the very best frame of mind. Above all, too much babbling and injudicious talk is to be avoided. The generalities, weak platitudes, and stereotyped consolations, so common at such times, are worse than useless; they tend to confuse and distract the mind, and are in the highest degree opposed to that tranquillity so essential. It is lamentable to see

with what a babble of tongues the poor sufferer is sometimes assailed. This is all wrong. The patient's thoughts are not to be burthened with affairs; his inquiries are to be patiently and frankly answered, and every encouragement afforded him which a sanguine view of the case will admit. If the surgeon himself is quiet, composed, self-reliant, his patient soon feels the exaltation of a similar temperament, and coming to regard his attendant as master of the situation, the mind passes from a state of agitation to one of calm and hopeful confidence. In a word, the patient is to be prepared as carefully as may be for every important operation. If the subject is to submit to the knife for the cure of deformity, for the relief of chronic disease or injury, he should be confined to his bed for several days previously, so that his system may not be surprised, as it were, by a too sudden change of his habits. This was a leading rule of a great and successful American surgeon, and long before Dudley's day, Travers asserts that his friend, Mr. Young, in cutting for stone or other such cases of surgery, used to put his patient to bed some days beforehand."[1]

The curative treatment of shock has for its object the restoration of the energies of the nervous and muscular systems; and it is highly important that the surgeon should succeed in establishing reaction with the least possible delay, in order that he may avoid, as far as possible, the subsequent danger which may arise from delayed shock. Dr. Ashhurst says, on this subject, that: "It is probably due, at least in the majority of cases, to the formation of coagula either in the heart itself or in the great venous trunks; this is a very fatal condition, and not unfrequently causes death after operations. Heart clots may kill the patient directly by mechanically impeding the cardiac action, or portions of a clot may become detached and be carried by the circulation into other parts of the body, where they may prove fatal by plugging important vessels such as the branches of the pulmonary artery, the internal carotids, etc."[2]

[1] Richmond and Louisville Med. Journal, vol. xxvi. p. 533 *et seq.*

[2] The Principles and Practice of Surgery, by John Ashhurst, Jr., M.D., 1871, p. 137.

It is now apparent that the only danger in cases of shock arises from the cessation or embarrassed action of the heart; and consequently all the treatment should be directed to increasing the force and regularity of the cardiac pulsations. It is nevertheless necessary to understand the physiological condition of your patient; since it is a well-known fact that the heart may be paralyzed by over-distension, and likewise that it cessation or embarrassed action may depend entirely on a deficiency of the blood supply. In the former condition it has been shown by experiments on animals, that "even after all pulsations have ceased, the heart's action can be restored by mechanically relieving the organ by a puncture in the right auricle or in the jugular vein; hence, the inference is reasonable and is confirmed by experience, that when, as in shock, death is imminent from engorgement of the right side of the heart and venous trunks, relief may be afforded by bloodletting. To make this as effective as possible, the blood should be drawn from the jugular vein. It is, of course, only in extreme cases, and in such as have not already suffered from hemorrhage, that this mode of treatment can be required, and it should be looked upon as an extreme remedy."[1]

In all those cases of shock, where there has been considerable hemorrhage, and in consequence of which there is a deficiency in the quantity of the natural and necessary cardiac stimulant, much good may be accomplished by elevating the extremities thereby increasing the quantity of blood sent to the heart; but the same object may be more satisfactorily accomplished by bandaging the extremities. The great advantage gained by the latter procedure over the elevation of the limbs, arises from the fact that it does not interfere with any of the other important details of the treatment, and requires no further attention, if the application has been properly made, until the time comes for the removal of the bandages. In addition to the means which have been already mentioned, the possibility

[1] The Principles and Practice of Surgery, by John Ashhurst, Jr., M.D., 1871, p. 135.

of employing transfusion advantageously in some of these cases is certainly entitled to our careful consideration.

The surgeon should never forget that the chief object in the treatment of shock is to increase the force and regularity of the heart's action. It is for the purpose of accomplishing these indications that he employs both internal and external stimulation. Dry heat should be applied to the surface of the body by means of hot bottles, hot bricks, or such other means as may be at hand. In all cases of severe shock there should be promptly given hypodermically injections of brandy or ammonia; since the absorption of fluids in the stomach goes on very slowly in these cases. In addition to these hypodermic injections, the patient should be made to inhale the fumes arising from ammonia, nitrite of amyl, etc. The patient should, at the same time, be kept as quiet as possible in the recumbent position; while sinapisms may be applied to the chest, abdomen, and the inner aspects of the thighs. In addition to the above-mentioned means, its also important that the lungs should be freely supplied with pure air, and this may necessitate the opening of all the windows in the sick chamber, or even fanning the patient. During the actual existence of shock it is highly important that the patient should be disturbed as little as possible, and even the bedding, with which the body should be kept well covered, ought not to be unnecessarily moved. There are unquestionably some cases in which it may be advantageous to administer a stimulating enema of the oil of turpentine, which may be beaten up with the yelks of eggs or mixed with a mucilage; but the quantity injected into the bowels should not be so large as to be soon after expelled. Thus far we have only mentioned internal stimulation by means of injections and inhalations, and the remedial agents enumerated have been limited to brandy, ammonia, nitrite of amyl, and the oil of turpentine. The treatment by injections is especially applicable in all cases of profound shock, attended with complete insensibility, although in addition to it some good may he accomplished by the inhalation of the fumes of ammonia, nitrite of amyl, etc. In the milder forms of shock the internal stimulation may be

effected by the introduction of the stimulants into the stomach. In these cases, there may be employed in addition to the remedies which have been already mentioned, strong hot coffee, beef essence, etc. The patient should also be relieved from pain as far as possible; this may be accomplished in some instances, by placing a mutilated extremity in a more favorable position, but in other cases it will require the use of morphine. There are likewise instances, where there is great mental depression, in which a few encouraging words from the surgeon kindly spoken, exert an almost magical influence.

Dr. Frederick James Gant has called attention to the fact that in some cases of shock "death may be sudden from spasmodic contractions of the heart, not followed by relaxation; this mode of syncope occurring from some sudden and violent impression on the nervous system. Or, more frequently, the fatal termination is equally sudden, though perhaps gradual, as the effect of the cessation of the muscular contractility of the heart."[1] In all instances where cessation of the heart's action has occurred, or is evidently about to occur, in cases similar to those mentioned by Dr. Gant, if unaccompanied by hemorrhage, the surgeon should resort promptly to the use of electricity and artificial respiration as the only rational mode of treatment for this class of cases.

Accidental Hemorrhage.

Subsequent to the performance of amputations, the surgeon is frequently annoyed by a hemorrhage which comes on with the reactionary excitement that follows shock. This hemorrhage commonly occurs within twenty-four hours after the performance of an amputation, and its occurrence is generally associated with the reactionary excitement; but it is only indirectly dependent on the same.

Accidental hemorrhage frequently depends primarily on the imperfect application of the occluding means: as, the tying of a vessel so near its cut extremity that the noose slips; the care-

[1] Science and Practice of Surgery, Amer. edition, Phila. 1878, vol. i. p. 329.

less formation of the knot, including a portion of the surrounding soft tissues in the noose of the ligature; failure to tighten the noose sufficiently on the artery to restrain the bleeding during the reactionary excitement; and secondarily all these casualties are commonly due to a diminution in the force of the heart's action, thereby arresting or diminishing temporarily the flow of blood from these arteries. Furthermore, the surgeon is still more embarrassed by the changes that take place in and around the vessels themselves. These changes consist in the retraction of the arteries within their sheaths, in the contraction of the cut ends, and in the formation of coagula around their exterior, and others within their interior. Whenever an artery is divided it immediately retracts within its sheath, and this of itself is often sufficient to close a small vessel. The division and contraction of the artery cause the blood to be projected through an uneven channel, which strongly favors the tendency to coagulation that already exists by virtue of the diminution in the propulsive force. These agencies which have been mentioned above, are so powerful, that an artery when first cut during the performance of an amputation, which throws out a stream of blood as large as a straw, will finally cease to bleed. The accidental hemorrhage takes place with the restoration of the force of the heart's action, from those arteries which the surgeon had failed to properly secure, owing to the existence of embarrassing circumstances. It should, however, be mentioned here, that there are other conditions which may lead to this accident; although it is believed that they are all more or less dependent on the contraction of the cut arteries, and the resulting formation of coagula within and immediately external to the same. It occasionally happens that the principal artery, which had been securely ligated near the point at which it was divided, is found to be insecure and even dangerous, owing to a puncture made into it during the operation, above the point of its ligation. The same trouble may arise when a collateral branch has been divided near the main artery, but which the surgeon has failed to secure, as there was no hemorrhage from it after the first gush of blood. There are many other conditions which

have their influence in the production of this form of hemorrhage, such, for instance, as disease of the arteries, and their abnormal distribution, hemorrhagic diathesis, the locality of the operation, etc.

It cannot be denied, that accidental hemorrhage may, and does *occasionally occur*, after the performance of amputations of the extremities, in the practice of the most careful surgeons; and, furthermore, that it is especially annoying in the practice of antiseptic surgery, since it is rarely safe to delay opening the stump, even though the loss of blood does not exceed a few ounces. *In the treatment of a case*, it therefore becomes absolutely necessary at this point of the procedure to differentiate between an accidental hemorrhage and the profuse oozing which occasionally follows the performance of an amputation, in which a rather strong solution of carbolic acid has been employed on the cut surfaces. This differential diagnosis is easily made by the color of the blood, which in all cases of accidental hemorrhage, possesses the bright red which is always characteristic of the arterial fluid; while in cases of oozing, the color of the liquid which flows from the drainage tube is, at first, of a dark or venous red; but it soon becomes lighter from the admixture of serum. The surgeon having recognized the fact that he has to deal with a case of accidental hemorrhage should generally proceed immediately to open the flaps and secure the bleeding vessels. It is well to remember here, that any arterial hemorrhage occurring with the reactionary excitement, commonly comes from an artery of considerable size; since nature's efforts and the pressure exerted by the wound dressing would have effectually controlled any flow from the smaller vessels.

Traumatic Delirium.

Prof. Erichsen, in the last edition of his *Science and Art of Surgery*, mentions two conditions under the head of "Traumatic Delirium," and remarks: "This disease presents two distinct types, which are, in fact, different diseases, the one *inflammatory*, the other *irritative*." The principal etiological difference in

these varieties of traumatic delirium is found in the septic complication which frequently exists in connection with traumatic inflammation; and the only semeiological difference is found in the sthenic character of the symptoms in the former condition as compared with the latter, which is markedly an asthenic disease. Both forms of traumatic delirium generally occur after the receipt of severe injuries, in persons of an irritable nervous system, especially in those who are much addicted to the use of intoxicating liquors. It commonly occurs before the fourth day, and generally declares itself during the night.

Prof. Gross says on this subject that: "In the great majority of cases they are produced, either directly or indirectly, by the inordinate use of alcoholic spirits, suddenly interrupted by the occurrence of a severe injury, attended, it may be, by dreadful shock, or copious hemorrhage, thus greatly increasing the susceptibility of the nervous system to external and internal impressions. It is not necessary for their development that the individual should have been a habitual drunkard; they often show themselves nearly as readily if he has merely been a free-drinker without having carried the use of liquor to the extent of intoxication. On the other hand, they occasionally occur in persons of the most temperate habits, who have perhaps never used alcohol in any form, or for any purpose whatever. Dupuytren, who first called attention to this variety of the disease, has given it the name of nervous delirium, and in the paper which he published on the subject he has reported a number of cases in which it supervened upon various kinds of injuries and operations, some of them of a very trivial character, or such as usually produce no unpleasant results of any description, the patient rapidly recovering from their effects. It cannot be doubted that in these cases, the affection is generally of a purely nervous nature, arising from the effects of the commotion inflicted upon a delicate and highly susceptible constitution. Under such circumstances, it is often mixed up with the effects of shock, rendering it difficult, if not impossible, to distinguish them accurately from each other. All practical surgeons have frequent opportunities of witnessing such cases. So far as my

observation extends, I am not aware that any class of injuries is entirely exempt from the disease; sometimes the most trivial scratch, or contusion, is followed by it. Corpulent persons, who generally bear injuries and operations very badly, are particularly prone to this form of delirium. Burns and scalds, railway lesions, lacerated wounds, and compound fractures may be enumerated as among the most powerful causes of the affection. It has been thought that children are less liable to suffer from nervous delirium than adults and elderly subjects; but this is certainly not true; on the contrary, such is the susceptibility of the system at this tender age to physical and mental impressions that the slightest accident is often sufficient to develop it. If women are less frequently affected than men, it is simply because they are less exposed to the various exciting causes of the disease. There is certainly every other reason why they should suffer quite as much as men, if indeed not more."[1]

Inflammatory Traumatic Delirium

is characterized by a quick and bounding pulse, hot skin and head, flushed cheeks, glistening eyes, much thirst, and high febrile action. The delirium is commonly wild or furious in this form of the disease. The patient shouting, cursing, singing, moving himself about in bed, without any regard to his own comfort or safety. The injured limb is frequently thrown about in such a manner as to impress the bystanders with the idea that the patient is entirely insensible to pain as well as to his own well-being.

Nervous Traumatic Delirium

commonly occurs in persons of a broken-down constitution and strongly resembles the ordinary *delirium tremens;* but it may be easily distinguished *from it by the absence of the tremors which form the most characteristic symptom of the latter disease.*

[1] System of Surgery, vol. i. 1866, p. 412 *et seq.*

It should also be remembered that delirium tremens frequently occurs after the receipt of an injury or the performance of surgical operations ; and there is good reason for believing that some authors include these cases with those of nervous traumatic delirium. The nervous traumatic delirium is sometimes preceded by a fit of an epileptiform character, but its absence has no diagnostic importance. In this form of the disease, the delirium is commonly of a low muttering character, the pulse is quick, small, and irritable, the countenance pale and haggard, sometimes anxious, although more frequently devoid of any marked expression, the pupils are commonly dilated, although occasionally contracted and insensible to light, the surface of the body is cool and covered with a cold perspiration, while the tongue is white and often slightly tremulous. These patients are occasionally harassed with spectral delusions, which may assume as many different forms as those which characterize delirium tremens. The delirium may be slight or very marked. In a case which recently came under my notice the symptoms were of an unusual character. The patient's temperature was about two degrees lower than normal, pulse 130 per minute and irregular, respirations 30, face of a pale dusky hue, eyes sunken, pupils greatly contracted and insensible to light, countenance anxious, body covered with cold sweat, tongue white, etc. This patient was constantly moving, it required the entire attention of a nurse to keep him in bed, and when not otherwise employed he was incessantly picking at the bedding. At the same time this patient was constantly muttering, but he could not be sufficiently aroused to answer questions. An amputation of the thigh had been performed forty-eight hours prior to the notation of the symptoms which are recorded above ; but the traumatism which necessitated the operation had been received twenty-four hours earlier. This patient was much addicted to the use of alcoholic stimulants and badly nourished, but nevertheless there was a complete absence of that peculiar trembling which characterizes *delirium tremens*.

Prof. S. D. Gross says : "It is well known that persons addicted to the immoderate use of opium and tobacco are

liable to suffer from a peculiar form of nervous delirium after severe injuries and operations, characterized by excessive wakefulness, and a sense of indescribable wretchedness, with a bewildered and confused state of mind, from which it is sometimes extremely difficult to arouse them, so as to induce them to take their necessary food and medicine. It is not improbable that the excessive use of coffee and tea may, in persons of a very nervous, excitable temperament, produce similar effects.

"In general, as was previously intimated, traumatic delirium usually sets in at an early period after the application of the external injury that provokes it; sometimes, however, the patient, perhaps contrary to expectation, goes on exceedingly well for some considerable time, happily surmounting the primary effects, but suffering severely from the secondary, the consequence commonly of profuse, unhealthy, and exhausting suppuration. Again instances occur in which he may have several attacks of this nervous suffering, with a variable interval of several days to several weeks, during which the mind may be perfectly clear and tranquil, the patient bearing up manfully under his disorders, sanguinely and fully anticipating none other than the most favorable termination."[1]

The Treatment of Traumatic Delirium,

whatever may be the form of the malady or its etiology, is always unsatisfactory and frequently unsuccessful. The first effort in the management of the severer forms of this disease, must be directed necessarily to restraining the patient in order that he may do no harm to himself or others. Moral force will be of no avail, since the patient can neither reason correctly nor understand the force of the arguments presented by others. Consequently the strait waistcoat becomes indispensable in the treatment of some of these cases. The application of the strait-jacket ought not to be made too hastily, since in some cases it would unnecessarily annoy the patient, increase the existing

[1] System of Surgery, vol. i. 1866, p. 413 *et seq.*

restlessness, and therefore diminish the chances for recovery It is therefore proper in all these cases before resorting to this mode of restraint, to place over the patient a careful watch, who should be instructed *to use no more force than is actually required to prevent the patient from doing harm, indeed the same rule should be applied to the application of physical force in all cases of surgery and under all circumstances. The treatment of inflammatory traumatic fever* may be somewhat depletory, although it would be unquestionably wrong to resort to venesection. The administration of a cathartic, followed by some sedative medicine, is often attended with marked benefit; but in all cases an effort should be made to procure sleep, and the diet should be properly regulated. The tincture of digitalis may be employed in these cases in large doses, with marked advantage, and when the same is combined with or followed by the bromide of potash and the hydrate of chloral, the most happy results may be expected.

The treatment of irritative traumatic delirium requires that stimulants, especially alcoholic, should be freely administered; and that in connection with this treatment a thorough effort should be made to procure sleep. In these cases opium has been employed with much apparent success; and the administration of two grains, as the first dose, should be followed by grain doses at intervals of two hours, until the desired effect is obtained. The hypodermic injections of morphia may be frequently substituted advantageously for the opium, especially when patients cannot or will not swallow. It is also highly important that the patient should receive the requisite amount of food, which should be of the proper quality and easily digested.

AN EXPERIMENTAL AND CLINICAL INQUIRY INTO THE ETIOLOGY AND DISTINCTIVE PECULIARITIES OF TRAUMATIC FEVER.

Prof. Billroth says: "I am firmly of the opinion *that wound fever and inflammatory fever generally, chiefly depend upon a poisoned condition of the blood, and that they can be produced by different materials which escape from an inflamed part into the*

blood."[1] This distinguished author, as if to render more emphatic the same idea, employs, on another page, the following language: "If a wounded man gets fever I conclude, whether the wound stink or not, that a phlogistic tissue decomposition is taking place, and its products have entered his blood."[2] The idea here expressed is a deduction drawn principally from experiments made on animals by Billroth, which consisted in introducing into the cellular tissue beneath the integument, or directly into the veins, pus, ichor, and various putrefying organic fluids, which invariably excited local inflammation, fever, and other constitutional disturbances.

A similar series of experiments was made on animals by C. O. Weber, with like results. These experiments were made with fluids taken from inflamed and suppurating wounds, which freely communicate with the air, and in which, according to our present opinion, there was already going on decomposition, and which, therefore, contained septic germs.

Prof. Ernst Wagner merely reiterates the opinion expressed by both Billroth and Weber, when he says: "It is absolutely established that the mode of injury and its immediate consequences, as far as effects upon the tissues are concerned, do not by themselves constitute factors capable of explaining the states of the temperature referred to above. . . . . All the remaining phenomena of traumatic fever in man are best explained by the hypothesis, that it is dependent upon inflammation set up, not by the injury itself, but by septic processes taking their start in the wound. It is most probable that the fever is caused only by spores which enter the blood through the wound, and that sepsis is the result of vibrionic putrefaction."[3] The idea so concisely expressed in the above has already been the subject of much initial thought and discussion among surgeons for more than one hundred years. During this period many surgeons have contended that the cause of inflammation and suppuration in wounds was due to atmospheric influences, while a very ancient

[1] Lectures on Surgical Pathology and Therapeutics, vol. i. p. 125.
[2] Ibid. p. 123.
[3] General Pathology, p. 672, N. Y. 1876.

idea attributed nearly all the evils arising in connection with a traumatism to the pseudo-demon cold. The numerous and ever changing views of the etiology of traumatic fever, which have been promulgated in the different centuries, beginning with Hippocrates, and coming down to our time, reflect for each age the true condition of the medical and other allied sciences; but it is sufficient for our purpose to state, that nearly all these theories may be classified as the septic, nervous, and nervo-septic. The question, however, here entitled to priority is, *What do we understand by traumatic fever?* Richerand says: "Traumatic fever is an inseparable companion from all wounds of a certain extent healing by suppuration." Dupuytren says: "Traumatic fever is a diseased condition following the receipt of a more or less severe wound, which has for its object the preparation of the wound for healing." C. O. Weber defines traumatic fever as a general increase of metamorphosis of the various substances of the body, accompanied by an elevation of temperature, which is caused by poisoning the blood with the products of the decomposed tissues, which act as a ferment and produce a rapid loss of body-weight. M. Verneuil declares that traumatic fever is a constitutional disease, accidentally caused by the introduction of traumatic virus, and he designates it "traumatic septicæmia." He adds, that in consequence of a small quantity of virus, and the rapid elimination of the same, in some cases the disease is very slight and fugitive. This is what happens in simple traumatic fevers; it is a diminutive characteristic manifestation of septicæmia. The definitions already cited form only a minor part of those which have been published, but the others differ from these principally in the language chosen to express the author's views rather than in the subject matter.

A majority of these definitions are intended to convey the etiological idea of the disease, but granting to them correctness in this particular, then it must be admitted that the use of the term *traumatic* instead of *septic* is certainly to be regarded as unfortunate, especially since many severe traumatisms are not attended with fever. Another objection to these definitions is found in the fact that recent observations and investigations in

connection with the practice of antiseptic surgery render it exceedingly probable that there is frequently developed in connection with a wound, a fever which differs in nearly all the essential characteristics from that arising from septic absorption.

The attention of surgeons was first called to this subject by Genzmer and Volkmann, in an article entitled "UEBER SEPTISCHES UND ASEPTISCHES WUNDFIEBER."[1] The authors of this paper have carefully pointed out the clinical peculiarities of each morbid condition. They remark that the most important manifestation of the septic traumatic fever is produced on the nerve centres by the toxic action of the absorbed material. We must admit that there result from it exclusively, or at least principally, the general feeling of illness, the diminished sensibility which we see increasing in severe cases of septicæmia to the point of sopor, the somnolence or apathy in other cases, the unfitness for mental efforts, the hallucinations, the formal sort of intoxication which occasionally causes the prostration of strength which may increase in severe cases of this fever until extreme weakness has been produced, and more or less directly derangments of the secretory functions, and also of the digestive apparatus on which depends the slight inclination for food as a most important clinical symptom. They now add, that *all these symptoms are wanting when a patient is suffering from the purely non-septic form of the disease, which in the former instance convince him that he is sick.* The increased temperature is almost the only, certainly *the only important* clinical symptom. Patients with a temperature of 102° to 104°, and even higher, go about, amuse themselves, are talkative and merry, smoke and play cards. Children with a similar temperature are found playing, while women and girls sit up in bed, and engage in sewing and knitting.

A patient with both arms amputated, who was treated by Lister's method, and whose wounds healed by first intention, walked all over the house on the day after the operation, and continued to do so subsequently, with an axillary temperature

[1] Sammlung Klinischer Vorträge, No. 121.

of 104°, amused every one about him, sang songs, and finally left the house and played buffoon. Another patient, who had received a compound fracture of the leg, besides an extensive contusion of the soft parts with loosening of the skin, which extended from the knee to the malleoli, and who showed an axillary temperature of 105.8°, did not exhibit the slightest trace of illness, and, although allowed the richest hospital diet, was not really satisfied. Incisions varying in length from two to three inches were made at the first dressing, and afterwards the wound was thoroughly disinfected and proper drainage established. These cases show the marked clinical difference in the constitutional symptoms of *septic* and *non-septic* fever arising in connection with wounds. The examination of a *non-septic* wound cannot fail in this connection to be interesting and instructive, since every surgeon will readily contrast the symptoms found here with those which prevail in wounds where the antiseptic precautions have not been observed. The non-septic wound is characterized by the complete absence of putrefactive odors, inflammatory reaction, local heat, redness, or œdema. The wound secretion after the first forty-eight hours is either entirely wanting, or else very slight, and is found on examination to be chiefly serous or mucous, although it may contain a few pus-globules. The absorption of this discharge is entirely harmless, as has been frequently shown, accidental displacement or occlusion of the drainage-tube, thus causing the retention of this fluid in the wound frequently for several days at a time. Even in these cases no inflammatory reaction follows, neither are the lymph-glands swollen; and the only harm done to the patient arises from the mechanical separation of the parts, which must delay or even prevent union by first intention. Analogous to the facts mentioned above, are the changes that take place in cases of simple fractures and severely contused wounds, when the injury is done to the cellular, adipose, and muscular tissues without destroying any portion of the integument. In these cases more or less of the tissues undergo a *non-putrefactive decomposition*, which is followed by a perfectly harmless absorption of their products. The circulation is destroyed in con-

siderable portions of the various tissues, even including the osseous, in cases of simple fractures, and nature has provided this instructive and harmless method for their removal. The medical profession is already so familiar with putrefactive decomposition, and its resulting septic absorption and blood-poisoning, with its grave symptoms and frequent fatal termination, that it is wholly unnecessary here to furnish details in order to enable a comparison to be made between it and the *non-putrefactive decomposition*. It is a well demonstrated fact that the former arises in putrescible substances which have been in some way exposed to contamination, most frequently by being open to the air; while in the latter case, although the material may be the same, the exposure and contamination have been avoided. We, therefore, observe putrefactive decomposition, septic absorption, and septic fever in the wounds which are open to the air; but in those wounds which are purely subcutaneous, or, if open, where the antiseptic method of treatment has been successfully applied, there is found only the *non-putrefactive* decomposition, harmless absorption, and a non-septic fever, which has neither pathological nor prognostic signification. Our inquiry brings before us two varieties of fever: one of unquestionable septic origin, whilst the origin of the other is certainly *non-septic*. The former is shown to be accidental, and in most instances avoidable open wound complication; whilst the latter has only been observed in connection with the practice of antiseptic surgery. Furthermore, septic fever is only one of a group of symptoms observed in all cases of septic blood-poisoning, while these morbid conditions are properly designated as septicæmia, septo-pyæmia, pyæmia, etc. *We, therefore, conclude that the application of the term traumatic fever to that morbid condition arising from the absorption of the products of putrefactive decomposition is a misnomer; and it is still an open question whether it ought to be applied to the non-septic fever, which was first described by Alfred Genzmer and Richard Volkmann*, in an article entitled *Klinischer und experimentelle untersuchungen über das Wund-*

fieber bei die antiseptischen Behandlung.[1] The latter refers to the differential diagnosis made by Genzmer and Volkmann, and declares that the opinion expressed by them is correct, and, further, that traumatic fever cannot be due to sepsis, as Billroth had supposed, since all the symptoms of septic poisoning are wanting. He has carefully analyzed twenty-four surgical cases which were treated antiseptically; among these were nine who had no fever, while fifteen suffered from a non-septic form of traumatic fever; but in the majority of these cases it only lasted one day, and in no case longer than seven. The highest temperature was reached as follows: 9 cases on the first day, 4 cases on the second, 2 cases on the third; but in a report of 12 cases by v. Wahl, the highest temperature was reached as follows: 1 case on the first day, 6 cases on the second, and 5 cases on the third. The highest temperature, when we include both these reports, which give us a total of 27 cases, was reached as follows: 10 cases on the first day, 10 cases on the second, and 7 cases on the third. The maximum temperature 103.4° in the twenty-seven cases was reached on the first day.

My own observations in connection with the practice of antiseptic surgery have been wholly confirmatory of these records, as well as the statements made by Edelberg, Genzmer, and Volkmann in regard to the *non-septic* character of this fever. The increased fever is the only evidence which these cases commonly present of any departure from the ordinary state of health, even after the performance of amputations and other severe cutting operations. It is only in exceptional cases that I have observed the face to be slightly flushed and the pulse a little accelerated, and even in these cases I am unable to recall a single instance where the functions of the body have not been well performed, and the patient able to eat, sleep, and enjoy himself. In all cases under my observation, the highest temperature has been reached on or before the third day after the

[1] Deutsche Zeitschrift für Chirurgie, 1880, S. 62.

operation, and the fever commonly disappears on or before the seventh, if the antiseptic treatment has been strictly adhered to.

Edleberg has already called attention to the fact that there is complete absence of all fever in a considerable number of these operations which are treated antiseptically; and, furthermore, that the cases in which this happens are commonly among the less severe major operative procedures. Unquestionably this statement is confirmed by the experience of most surgeons, and I have before me the complete notes of a case of amputation of the leg through the upper portion of the lower third, which was performed about 8 P. M., September 1, 1879. The highest temperature was 100.2°, and occurred on the morning of September 3d. The normal temperature was reached on the morning of September 7th. The average daily temperature until the normal was attained, was, in the morning, 99.1°, and in the evening 99.6°. The wound had completely healed, and therefore the patient was discharged on October 1st. The pulse never rose higher than 88 during any part of the treatment. The patient remained cheerful during the whole time that he was under my care; ate well, slept well, and actually increased in weight during this month.

Having already presented a few essential points on the subject of the non-septic traumatic fever, together with clinical illustrations of the same, we will now proceed to investigate its etiology. In the performance of this work, we are prompted to ask what are the chief factors involved in those injuries and operations which are followed by this fever. We have already incidentally mentioned that the open wound is an essential condition for the development of septic fever, but its relations to non-septic traumatic fever are still to be determined; however, thus far it has only been observed and studied in connection with the practice of antiseptic surgery. It therefore seems proper to commence our investigation with an inquiry into the effect on the temperature of the various complicating factors of an open wound; and among these may be mentioned shock, loss of blood, the action of carbolic acid, and anæsthetics, especially chloroform and ether. Edelberg has brought before

us the views of various authors on the parts performed by some of these factors, and after having experimentally examined them, he gives the conclusions thus reached.

Credi has suggested that the traumatic fever following an operation may be explained as reaction from the lowered temperature associated with the operative procedure. Edelberg in reply calls attention to the fact that, if this opinion is correct, then this fever ought to arise in every case when the temperature has been lowered during the performance of a tedious operation, and, on the contrary, if the operation has been of short duration, and attended with no lowering of temperature, it should be followed by a complete absence of the fever.

Experience has shown, however, that this beautiful theory is not confirmed by practice, and is, therefore worthless. Edelberg refers to the undecided position of Billroth in regard to the action of chloroform on the temperature, and then proceeds to make three experiments on healthy dogs, by which he shows that the effect of the drug is to lower the temperature without being followed by any reactionary fever. This conclusion is in harmony with the experimental results obtained by Duméril and Demarquay in 1848. He then proceeds to the examination of the opinion expressed by Sonnenberg and Küster, that the fever observed during the antiseptic treatment of wounds is due to the poisonous action of the carbolic acid. He cites on this point Hoffmann and Dumion, who find that the administration of this drug produces, after a trifling increase at the commencement, a constant lowering of the temperature, and, he adds, as regards carbolic acid producing the fever, all experimenters agree, except Sonnenberg and Küster, that it exerts the opposite effect.

Edelberg also performed numerous experiments on cats and dogs, administering the drug endermically, hypodermically, by the mouth, and by rectal injections. He introduced it into the stomach through a tube in order to avoid unnecessary irritation, and in seven cases he inserted it in a pilular form into the rectum. He admits that the introduction of a large quantity of this acid in a concentrated form into the stomach may be followed by a

violent gastro-enteritis, and thus cause a rise in the temperature, but denies the possibility of producing this effect unless the drug is employed in such a form as to produce its escharotic action. He furthermore adds, that chloroform may be as properly charged with producing fever as carbolic acid. The carefully detailed experiments performed by Edelberg on animals for the purpose of determining the etiology of traumatic fever ought certainly to exclude carbolic acid from all direct agency in it. This experimenter gives little attention to the loss of blood in connection with traumatic fever, but the explanation of what appears to be an omission may be possibly found in the fact, that other works have already shown it to be unimportant in its bearing on wound fever. It is a well-known and undenied fact that hemorrhage produces a rapid lowering of the temperature, followed under favorable circumstances by a moderate and brief reaction. Pain produces a moderate elevation of the temperature; but neither it nor the loss of blood, is entitled to much consideration in connection with wound fever. Physical exertion and mental emotions may likewise produce changes in the temperature, but since they are both essentially transient conditions and with little bearing on our subject, they may consequently be dismissed here without any further consideration.

The examination of traumatic fever by Genzmer, Volkmann, and Edelberg, led them to the conclusion that this morbid condition depended on the absorption of some non-septic material from the wounds. These conclusions, and the many interesting facts developed during their investigations, prompted Dr. John Van Vorst, Jr., and myself, to undertake a series of experiments which has just been completed, in which seventy rabbits were employed and eight hundred and ninety temperatures taken. These temperatures were all taken with thermometers especially constructed for this purpose, and which, on careful comparison, were found to agree accurately with each other at the various points of the scale, and, furthermore, the instruments were always introduced into the rectum the same distance, and at all times retained there five minutes.

The normal temperature of seventy rabbits, which had not

been operated on, was as follows: The maximum, 104.6°; the minimum, 100°; average (total), 102.7°. The normal temperature of forty-three rabbits previously operated on, but which had fully recovered, was as follows: The maximum, 104.4°; the minimum, 101.3°; the average (total), 102.9°. The normal average temperature of the one hundred and thirteen rabbits was 102.8°.

The details connected with the etherization of nineteen rabbits are briefly shown in the following: The average temperature prior to the experiment was 102.2°; the average time required to produce complete anæsthesia by the inhalation of the vapor of ether in the experimental cage was thirty-four minutes; and the average temperature while kept under the anæsthetic influence of this drug was as follows: One-half hour, 101.1°; one hour, 101.4°; one hour and a half, 102°; and two hours, 101.7°. It should be observed that these rabbits were kept continuously under the anæsthetic influence of the drug two hours, during which period the temperature was taken every half hour, and at the expiration of this time they were removed from the experimental cage and placed in the fresh air, where they soon regained their former condition, and the temperature was now noted on three consecutive days, care being taken to preserve an interval of twenty-four hours between each record, with the following results: First day, 102.6°; second day, 102.2°; third day, 102.3°.

It will be seen by the above figures that the first half hour that the rabbits were kept under the influence of the ether the average temperature was lowered one-and-one-tenth degree; however, during the succeeding hour the temperature rose to within two-tenths of a degree of what it was before the experiment began. The daily temperature indicates only a trifling and wholly unimportant reaction.

The following are the essential facts connected with the anæsthetic administration of chloroform to twenty-two rabbits. The average time required to produce complete anæsthesia was twenty-six-and-a-half minutes, and the average temperature

while kept under the influence of chloroform was as follows: One-half hour, 100.7°; one hour, 101.4°; one hour and a half, 101.2°, and at the expiration of two hours, 101.5°. The same care was taken in making the daily records after the administration of chloroform as had been observed when the ether was employed. The daily record of the average temperature was, on the first day, 101.8°; on the second day, 101.9°; and on the third day, 101.8°.

The rapid fall of temperature during the first half hour that the rabbits were under the influence of the ether was a marked feature of this experiment, but it will be observed that this primary effect almost wholly disappeared during the next hour, although the anæsthetic influence of the drug was continued. The depressing effects of chloroform as an anæsthetic are still more marked, and we observe at the end of the first half hour that the average temperature had been lowered two degrees and one-tenth instead of one-and-one-tenth. Furthermore, we observe that the reaction during the administration of chloroform is much less than when ether was employed. Even the normal average temperature had not been reached after the lapse of three days. The next condition investigated was that which is commonly designated as shock, since it frequently forms a complication in cases of wounds and severe operations. The object which we sought to accomplish by this investigation was a determination of the question, Is shock followed by a reactionary fever? It will be readily admitted that shock as a complication of a wound or operation is too intimately associated with the traumatism to be conveniently studied. We, therefore, sought in this case to produce shock without causing at the same time any organic lesion. We employed for this purpose a galvanic battery, and readily produced the desired effect by introducing one pole into the mouth, while the other was in the rectum. It should be mentioned that the severity of the shock varied considerably. However, none of the animals were able to run or even walk well after receiving their allotment, and one was observed to lie on his side, where he had been placed, more than five minutes, gasping at long intervals before he was able to

raise his head. The result of this experiment may be summed up as follows: Nineteen rabbits were employed. Average temperature before shock 102.8°; average temperature within two hours 102.8°; and the average temperature within thirty hours 102.8°. It may now be stated that the result of this experiment, as far as the production of any reactionary fever by shock is concerned, demonstrates a negative.

The next experiment which we will report consisted in fracturing the right leg of twenty rabbits. This was done without producing a single compound fracture. The temperature details were as follows: Average temperature before the fracture, 102.6°; average temperature two hours afterward, 102.6°; subsequent daily average temperature, first, 102.6°; second, 102.6°; third, 103.1°; fourth, 103.1°; sixth, 103°; eighth, 103.1°; tenth, 102.8; twelfth, 103°; fifteenth, 102.8°; seventeenth, 103.2°; nineteenth, 103°; twenty-second, 103°. It is shown by the above figures that the highest average temperature occurred on the seventeenth day. The temperature on this day was found to be six-tenths of a degree higher than that recorded immediately before the fractures were produced. A number of the fractures which were originally simple became compound during the period that the rabbits were under observation. As soon as any wound was discovered on the rabbits, whether in connection with the fracture or elsewhere, the temperature was no longer recorded, since it was our object here to avoid all septic complications. On the twenty-second day after the fractures were produced there was found to be pretty firm union. In the final experiment ten rabbits were employed, and the operation consisted in injecting into each, beneath the integument in the lateral lumbar region, one-half ounce of arterial blood. This blood in one instance only was taken from one rabbit and injected into another; but in nine cases the blood was obtained from a dog. We regarded it as very desirable to accomplish this part of the operation with the least possible exposure to the air, and at the same time to preserve essentially the normal temperature of the blood. We employed Freyer's transfusion apparatus, and the details of the operative procedure were as

follows: The dog having been anæsthetized, an incision was made down to the right common carotid, which was raised from its bed, and the handle of the scalpel placed beneath it, the proper canula was introduced, and secured in this vessel; the tube and bulbs had been previously filled with hot water, and the other end of the instrument supplied with an aspirator needle instead of the ordinary canula. The hair had been closely cut with scissors at the place where the needle was intended to be entered; the needle was passed through the centre of a sponge, which had been previously soaked and was still wet with a carbolic acid solution; the stopcocks were now opened, the hot water was quickly discharged, closely followed by the blood; the stopcocks were again closed, and the sponge quickly slipped down over the opening in the end of the needle; the rabbit's skin having been cleansed at the spot where the injection was to be made, was now moistened with the sponge covering the point of the needle; this sponge was then pushed back, the needle entered beneath the integument, the injection made, stopcock closed, needle withdrawn, and its aperture closed as previously described. In this manner the work proceeded until the whole number had been injected. The following figures indicate the slight fluctuations in the temperature observed in connection with this experiment. The average temperature before the injection was 103.2°; average temperature three hours after, 103.2°; average temperature one day after, 103.3°; and it was subsequently as follows: second day, 103°; third day, 102.8°; fourth day, 103.3°; fifth day, 103.2°; and the eighth, 103.2°.

The relatively large quantity of blood which was thrown into the cellular tissue in this experiment produced no perceptible effect on the temperature, as the fluctuations already noticed are not only within the limits of the normal variations, but are really so slight as to possess only negative value. The half ounce of blood injected into the rabbit bears about the same relation to the whole weight of the animal as twenty ounces would to one hundred and sixty pounds. This experiment would, therefore, seem to justify the conclusion that the absorption of a large

quantity of blood produces very little or *even no effect on the temperature*. Furthermore, it may be added that, within a few days, the blood was all absorbed from these tumors which had been produced by the injections; and that, without causing any local or constitutional disturbance, with only a single exception. In the exceptional case the tumor failed to disappear, and after the discontinuance of the temperature observations an abscess formed which opened, and the rabbit finally died from septic poisoning.

We have now presented separately the results of our experimental inquiry into the etiology of traumatic fever. This investigation was commenced for the purpose of determining, as far as possible, the effects on the temperature of the various factors which primarily complicate wounds and surgical operations, and we have consequently endeavored to avoid any coalition which could lead to septic complications. We are now convinced that the fever observed in connection with the antiseptically treated wounds does not owe its origin directly to the lesion, or its usual complications. Does it arise from the absorption of carbolic acid? Edelberg, who has carefully investigated this subject, gives us a negative answer; and we think that those who take the trouble to follow him studiously through his experiments will finally accept his conclusion.

This important question, What causes the *non*-septic fever? still remains unanswered. Genzmer and Volkmann have supposed that it originated in absorption from the wound, but do not designate the substance thus taken up. Another author, v. Wahl, has suggested that there may be a connection between the blood contained in the wound and the traumatic fever. Edelberg remarks on this subject, that should it really be proved that such a connection exists, then it is evident that this relation could only be by means of a fibrine ferment. He further adds: I have made, under the friendly direction of Prof. Alexander Schmidt, here in the physiological institute, a large number of experiments with fibrine ferment, the results of which I will publish *in extenso* in another place; as they are pathologically

very interesting, whilst here I must be content to state the conclusions drawn from them.

The essential points contained in these conclusions are as follows: The fibrine ferment in a certain quantity produces death by the coagulation of the blood; in a smaller quantity it gives rise to complex symptoms with a considerable rise of temperature, the latter being characteristic of the action of the fibrine-ferment; and, furthermore, the same class of symptoms may be produced by the injection of the watery extract of the blood, which does not contain any free fibrine-ferment. The result of these experiments led him to infer that the cause of the traumatic fever observed in connection with the antiseptic treatment of wounds should be sought for in the partly coagulated and partly fluid blood, instead of the carbolic acid.

In support of this position he offers these arguments. This view finds its best support in the character of the wound fever. Why do we see the temperature rise very rapidly after an injury, and usually reach its maximum on the first day, where there can be no question of suppuration and septic action, whilst, on the contrary, clinical observation shows that there is in the wound only blood or a bloody-colored secretion? He now brings forward in support of this hypothesis several typical cases of traumatic fever, in which there was found the characteristic condition of the wound, which has been previously described, and also other cases in which the absence of the coagulated blood and the bloody serum was further marked by a complete absence of fever. He remarks it would certainly carry me too far, if I should discuss from this standpoint all the cases which I have observed, and which seem to justify me in asserting, that traumatic fever may be properly regarded *as an absorption fever, and, indeed, only as an absorption* fever, produced by the absorption of blood (fibrine-ferment) from the wound. He further adds: Now, if this inference is correct, there must arise a similar fever in cases of simple fractures of the extremities associated with an extravasation of blood, and, in fact, practice rarely corroborates theory so completely as in these cases. Every surgeon has certainly had opportunities to observe that

simple fracture, if associated with more or less marked extravasation of blood, is also embarrassed by a high temperature. But to what ought the fever to be attributed? Should it not be regarded essentially as an absorption fever? I believe one will not be far from the truth if he answers this question affirmatively.

Having outlined as briefly as possible the experiments, arguments, and conclusions of Edelberg, whose publication gave rise to our experimental inquiry, although our clinical observations are of a much older date, we are prepared to express the results of our study as far as our investigations may warrant it. Let us now consider the question, Does traumatic fever arise from the absorption of subcutaneously extravasated blood? The experiment we made by injecting blood into the cellular tissue beneath the integument gives *to this question a negative answer*, and our own observations in surgical practice is confirmatory of the same. I can now recall to mind numerous cases of bloody tumors and subcutaneous blood extravasations, in which the absorption never gave rise to any fevers. *In fact these conditions are characterized by a complete absence of all fever, and the existence of fracture in connection with the extravasation does not change the rule.* We are therefore constrained by clinical observation and experimental inquiry to deny that traumatic fever has its origin in the absorption of subcutaneously extravasated blood; and, furthermore, while admitting its existence and peculiarities as described by Genzmer and Volkmann, we are firmly convinced that *it is never seen except in the practice of antiseptic surgery.*

Edelberg has satisfactorily shown that this fever does not arise directly from the carbolic acid, or from the chemical or physiological changes produced by the same in the tissues and fluids of the body, so long as they remain in their normal and healthy state and are not exposed to the air. He attributes this fever to the presence of fibrine-ferment or some similar substance which has been absorbed from the wounds, and which is primarily developed from the wound secretion,

but gives no information in regard to the agencies by which it was produced.

The experimental and clinical research which has probably already been sufficient to justify the exclusion of the majority of the wound complications from any active agency in the production of traumatic fever; and we are now led by our own investigation to believe that the cause of this fever should be sought for in the action of the carbolic acid on the wound secretion aided by the air; while the absorption of the new product is unquestionably the first step in the development of the morbid condition. Another fever, malarial in its character, is frequently found complicating recent wounds, and consequently it has been occasionally mistaken for traumatic fever. This complication is characterized by its prevalence in malarial districts, and its *regular succession of the cold, hot, and sweating stages*. The explanation of its development in connection with a traumatism is unquestionably found in the fact, that a latent malarial poison, which had not previously produced paroxysms, although the patient may have suffered with indefinite ailments, is now developed owing to a *lowering of the vital powers*. Therefore the malarial poison may be regarded as the predisposing cause, and the traumatism as the exciting agent in this complication.

During our inquiry into the etiology of traumatic fever, we have observed three distinct forms of disease which differ widely in their origin and distinctive peculiarities when seen as a complication of recent wounds. The term "traumatic fever" has also been improperly applied to the febrile condition which exists in pyæmia and septicæmia; since recent investigation has shown that wound fever is *a non-infective disease*, while the latter wound complications *are infective processes*.

The committee appointed by the London Pathological Society for the purpose of investigating the nature and causes of certain wound complications have reported in regard to septic traumatic fever, that, "ordinary wound fever is merely septic intoxication in a very mild form"[1] and "the poison does not multiply in the

[1] Transactions of the Pathological Society of London, 1879, vol. xxx. p. 14.

body, and consequently the blood of an animal which has been killed by pure septic intoxication, containing, as it does, only the original dose diluted, will not set up a similar affection in another animal."[1] The diagnosis of traumatic fever is never difficult; but it should be remembered that in both the septic and non-septic varieties there is generally no chill, while in all cases of malarial poisoning the chill is one of the most essential characteristics of this wound complication.

There is little treatment required for this fever, since the antiseptic treatment of wounds now so largely adopted, by preventing decomposition, of course renders septic traumatic fever impossible. However I am strongly in favor of the administration of liberal doses of quinine to all patients, who are suffering from a severe traumatism, during the first day of their illness, and the first dose should be given as soon after the injury as the stomach will tolerate it. It is also highly important that the various emunctories be properly stimulated to the performance of their duties, in all those cases in which nature is tardy or incompetent.

Secondary Hemorrhage, Causes and Treatment.

Dr. Dunglison, in his medical dictionary, says: "A *secondary hemorrhage* is one that occurs some time after wounds or operations;" while he mentions *accidental hemorrhage* as one produced by some adventitious cause. The majority of surgical authors have been accustomed to describe both of these forms under the head of *secondary hemorrhage*. The term "secondary" as here employed, presupposes a preceding hemorrhage, which is properly regarded as the primary. Esmarch has shown that it is an easy matter to amputate an extremity without the loss of blood, and consequently the term "secondary," when applied to any hemorrhage in these cases, loses much of its original force. The surgical authorities, who thus employ the term secondary hemorrhage, are unanimous in the opinion that it may

[1] Ibid. p. 12.

arise from a variety of causes, some of which are local and others constitutional. It will be found by carefully analyzing all these local causes, that the term *accidental hemorrhage* generally conveys a correct idea of the etiology of this wound complication, while the term "secondary" entirely fails in this respect. I have therefore considered under the head of *accidental hemorrhage* all these local causes which have heretofore been treated under the caption of secondary hemorrhage; and, consequently, there remains for our present consideration only that portion, which has been supposed to arise from constitutional causes. These causes have been succinctly arranged and tersely stated by Dr. John Ashhurst in the following: "The *constitutional* causes of secondary hemorrhage may be said to be any conditions of system which interfere with the natural processes which we have seen to be essential for the closure of wounded arteries. Thus, a want of coagulability in the blood itself, the 'hemorrhagic diathesis,' visceral disease (especially of the liver), an unusually severe attack of ordinary traumatic or inflammatory fever, certain affections which are apt to occur after operations, especially erysipelas, pyæmia, hospital gangrene, or even ordinary sloughing, may all be considered as causes of secondary hemorrhage. In the case of pyæmia, the hemorrhage often consists of capillary oozing—the *parenchymatous hemorrhage* of Stromeyer and Lidell—and is apparently due to mechanical obstruction, from thrombosis of the venous trunks of the part."[1]

An examination of the above citation cannot fail to satisfy any surgeon who is familiar with the surgical literature of the day, that septic infection is the *essential cause* of secondary hemorrhage; since the bleeding which occurs in cases of a "hemorrhagic diathesis" or visceral disease should be classified with *accidental hemorrhages*, inasmuch as it generally occurs during the reactionary excitement which follows the shock of the operation or injury. It cannot be denied that all the other morbid conditions mentioned by Dr. Ashhurst in his enumeration of the "*constitutional causes*" of secondary hemorrhages are

[1] The Principles and Practice of Surgery, Philada. 1871, p. 192 *et seq.*

unquestionably of septic origin, even the diminished coagulability of the blood. We, therefore, employ the term "secondary hemorrhage" with especial reference to the fact that it is always to be regarded as a secondary wound complication, while septic infection is the primary. The septic infection is commonly followed by both constitutional and local changes, and the secondary hemorrhage may be due either to the former or the latter. The constitutional changes in the septic diseases, which have been already mentioned, should always be regarded as a strong predisposing cause of secondary hemorrhage, while the diminished coagulability of the blood, the existence of thrombi in the veins, etc., are very frequently the proximate cause. The local changes which so frequently give rise to this unfortunate wound complication are generally inflammatory in character, leading primarily to the formation of pus, the infiltration of the tissues, and subsequently to the sloughing of the soft parts and the erosion of arteries, etc. In the majority of cases of secondary hemorrhage, the first bleeding having been sufficient to reduce the force of the heart's action, the further flow of blood is generally arrested by nature's own processes. The principal danger in these cases commonly arises from the successive hemorrhages by which the patient is reduced to a state of extreme anæmia, and dying from the repeated losses of blood, rather than from the quantity lost at any one time. Indeed, it should be remembered that in all instances of secondary hemorrhage, the loss of blood is *only one* of the septic influences, which are instrumental in the production of the fatal termination.

The treatment of secondary hemorrhage should be both prophylactic and curative; but the former ought to be employed so efficiently, in all cases of amputations of the extremities, that there would be no necessity for the employment of the latter, except in those cases where septic infection had taken place prior to the performance of the operation. The Lister system of wound treatment is unquestionably the *best prophylaxis* against all the various complications arising from wounds which *has ever been employed;* and consequently it should be strictly adhered to in all cases of amputation of the extremities,

in order to avoid secondary hemorrhage and other septic complications. This treatment should be employed in these cases, even to the exclusion of all the so-called "modifications," but, inasmuch as it has been already fully described in this work, it is unnecessary to repeat it here.

The curative treatment of secondary hemorrhage should be constitutional and local. The constitutional treatment should be directed to the relief of that septic condition which is the cause of the hemorrhage. In other words, the surgeon ought to endeavor in every instance to meet the indications of the case; but since the constitutional treatment has been fully given in our treatise in this work, on the various septic conditions arising in connection with wounds, it therefore requires no further consideration in this chapter.

The local treatment of secondary hemorrhage from a stump will depend chiefly on the character of the hemorrhage (profuse or slight), the condition of the patient (strong or feeble), and also the situation and condition of the stump. The following treatment is recommended by Mr. Erichsen for these cases: "If there be but slight oozing, elevating the part, applying cold, and bandaging it tightly with a roller, so as to compress the flaps, will sometimes arrest the bleeding. If it continue, however, or become more severe, the flaps, which will have been disunited by the effusion of blood, must be separated, and the bleeding vessels sought for and tied. When the stump is sloughy and the tissues softened, the ligatures will not hold; in these circumstances the application of the actual cautery to the bleeding points will arrest the flow of blood. If the oozing appear to be nearly general from the number of points, the flaps being somewhat spongy, I have succeeded in arresting the hemorrhage by clearing their surfaces thoroughly of all coagula, and then bringing them tightly together by means of a roller.

"If the hemorrhage occur at a later period, after the tenth day, when tolerable union has taken place, and if it appear to proceed from the principal artery of the part, an effort may be made to arrest it by the application of the horse-shoe tourniquet,

which occasionally will stop all further loss of blood; or, if the union that had taken place between the flaps have been broken through, the stump may be fully opened up, the coagula turned out, and the bleeding vessel sought for and tied. If, however, notwithstanding the hemorrhage, the union between the flaps continue sound and firm, then the choice lies between three alternatives; 1, opening up the stump, clearing away coagula, and tying the bleeding vessels at their open mouths; 2, ligaturing the main artery just above the stump; 3, performing the Hunterian operation, and tying the vessel high up in the limb at a distance from the stump. The course to be adopted will, I think, in a great measure depend upon the stump with which we have to do; but as a general rule I prefer in these cases adopting the first alternative, placing a tourniquet on the limb, passing the finger into the stump, and breaking up all adhesions which are often very firm; then turning out the mass of coagula which will usually be found distending the flaps, clearing these thoroughly with a sponge, and then tying the bleeding artery. If there be a difficulty in exposing this, or in clearing it so that the ligature will hold, acupressure may be substituted for the ligature, and the effects of this may be increased by the continuous employment of digital compression in the groin. Besides, the main artery that bleeds—one of the tibials, for instance, if it be a leg amputation—there will generally be very free oozing from many points. The more abundant of this may be stopped by the ligature, passed, if the tissues be friable, by means of a nævus-needle, under the vessels. The rest will cease on the application of cold water and on raising the stump. The flaps may then be brought together by strips of plaster and a bandage, and will usually very readily unite.

"Should, however, the stump be inflamed, sloughy, and œdematous, and more particularly if it be merely the foot or hand that has been removed, then, instead of opening it up, and seeking for the bleeding vessels, deeply hidden in infiltrated tissues, it will be better to tie the main artery of the limb just above the flaps, or wherever it can be most readily reached. In

such cases, after amputation of the foot, I have successfully tied the posterior tibial low down, just above the malleolus.

"The third alterative, that of ligaturing the artery high above the stump, should, I think, in the first instance, be undertaken in those cases only where the amputation has been done close to the trunk, as at the shoulder-joint, or the middle or upper part of the thigh, and where consequently there is no length of limb to be nourished by the artery that is ligatured, and where opening up an almost cicatrized stump of very large size would inflict a greater shock upon the system, and more subsequent danger, than the deligation of an artery by an independent operation. Hence, although in no cases of secondary hemorrhage from a leg stump below the knee would I ligature the femoral in preference to opening up the flaps and securing the vessels in them, if this were practicable, yet in secondary hemorrhage after the amputation of the thigh, the case might be different; and here, if good union had already taken place, and the stump were not distended by coagula, the main artery might be tied. In such cases it is clearly useless to ligature the superficial femoral, as the hemorrhage may, and most probably does, proceed from some of the branches of the profunda. Ligature of the common femoral is not very successful; and upon the whole it would, I think, be safer, if all other means have been tried, and have failed, to deligate the external iliac just above Poupart's ligament. In disarticulation of the arm at the shoulder-joint, the subclavian artery must be tied either above or just below the clavicle.

"In any case, the ligature of the main artery of the limb becomes the only and the last resource, where, in consequence of the softened, inflamed, infiltrated, or sloughy state of the tissues, the surgeon is unable to secure the bleeding vessels in the stump itself, the ligatures cutting through the disorganized coats of the vessels."[1]

[1] The Science and Art of Surgery, Amer. ed., 1878, vol. i. p. 318 *et seq.*

CHAPTER X.

PYÆMIA AND SEPTICÆMIA. HISTORY. NOMENCLATURE. PATHOLOGY. ETIOLOGY. SYMPTOMS. DIFFERENTIAL DIAGNOSIS. TREATMENT.

HISTORY.—The morbid conditions now designated pyæmia and septicæmia were recognized by the "Father of Medicine,"[1] who reports a well-defined case of puerperal fever terminating fatally on the twentieth day of the disease; and also the following fatal case of erysipelas: "Criton, in Thasus, while still on foot, and going about, was seized with a violent pain in the great toe; he took to bed the same day, had rigors and nausea, recovered his heat slightly, at night was delirious. On the second, swelling of the whole foot, and about the ankle erythema, with distension, and small bullæ (phlyctenæ); acute fever; he became furiously deranged; alvine discharges bilious, unmixed, and rather frequent. He died on the second day from the commencement."[2]

Further confirmation of the fact that Hippocrates was familiar with the phenomena of these diseases may be found in his dissertation on "Empyæma and Fevers."

Prof. C. Hueter, under the head of "Septic Fever," says: "Hippocrates and Celsus observed the fever in cases of injuries which proved so dangerous that this danger must have originated, not from the wound or inflammation, but from some unknown cause."

Jacotius, a commentator of Hippocrates, has even mentioned putrid fevers, the same as Adrianus Spigelius, who spoke of fevers which arise from putrefaction; but both authors, as well as their followers, did not discriminate between septicæmia aris-

[1] Works of Hippocrates, translated by Adams, vol. i. p. 373.
[2] Ibid. p. 377.

ing from the putresence of wounds, and pyæmia. In the meantime, both varieties were regarded as intermittent fever.[1]

"Aretæus lived during the middle of the second century of the Christian era. In his remarks on pneumonia, Aretæus observes that the subjects of this disease die mostly on the seventh day. 'In certain cases,' he says, 'much pus is formed in the lungs, or there is a metastasis from the side if a greater symptom of convalescence be at hand. But if, indeed the matter be translated from the side to the intestine or bladder, the patients immediately recover from the peripneumony.' He speaks of metastasis to the kidneys and bladder being peculiarly favorable in empyæma. He ascribes suppuration of the liver to intemperance and protracted disease, especially from dysentery and colliquative wasting. The symptoms described by him resemble those of chronic pyæmia."[2]

A new era in the literature of this subject dawned during the sixteenth century.

Ambrose Paré and Bartholomew Maggi each published a work in which they pointed out the old errors and announced new truths. Carl Thiersch, in his lecture on "Klinische Ergebnisse der Lister' schen Wundbehandlung und über den Ersatz der Carbolsäure durch Salicylsäure," says: "When, in the year 1536, a strong army of the 'famous King Francis' marched over Mt. Cenis into Piedmont, it was accompanied by an inexperienced surgeon only nineteen years of age, the subsequently so highly honored Ambrose Paré. The storming of the mountain citadel of Vallane, near Susa, gave him, indeed for the first time, plenty to do, and he put in practice everything in accordance with the example of his older colleagues. Like them, if also with fear, he poured boiling oil of elder into the gunshot wounds, in order to destroy the poison; but as there was not sufficient oil, he was compelled to dress the remainder of the wounds with a salve prepared from oil of rose and turpentine.

[1] Pitha u. Billroth, Handbuch der Chirurgie, 1. Band, 2. Abth. 1. Heft, 1. Liefg., 6. S.

[2] Braidwood on "Pyæmia," p. 2.

Pained by the fear that the latter, in a short time, would become a sacrifice to the poison, he passed a sleepless night, arose early from his bed in order to examine the unfortunates, but was greatly surprised to find the half-given-up almost free from pain, without inflammation or swelling. 'Then I determined,' said he, never again to burn the poor wounded soldiers so cruelly.'"

Paré's "Treatise on Gunshot Wounds" first appeared in Paris in 1551, fifteen years after the occurrence of the previously narrated event, in which he declared in favor of the non-poisonous character of these wounds. He had spent a part of the intervening time in Italy, and it is supposed that he there became acquainted with the investigations of the learned Bologna physician, Bartholomew Maggi, and had appropriated to himself the demonstrations on the non-poisonous nature of gunshot wounds. Maggi's treatise appeared a year later (1552), at Bologna. In whatever manner Paré may have obtained the priority, certain it is that he required all the influence which he in more mature years enjoyed, especially in things pertaining to military surgery, in order to provide a gradual introduction for the new theory. Still one meets with the old error among the more modern physicians. How this error could have attained such a widespread influence is, indeed, scarcely susceptible of demonstration. It is certain that, originally, gunshot wounds passed for contused wounds, and were usually treated with warm moist poultices. But as gunshot wounds are naturally inclined to a bad course, especially if complicated with a fracture, and as this bad termination has become more frequent since the introduction of firearms, depending on an increase in the number of that kind of injuries, while the care of the wounded at that time was always insufficient: in this way was encouraged the formation of a false opinion, based on the experience at the bedside, of the special danger of gunshot wounds.

Cases of acute sepsis which developed after the infliction of gunshot wounds, and which agreed in essential points with the results of the bite of poisonous snakes, had given a turn to events. There were such cases during the Franco-Prussian

war, which here and there among the laymen even excited suspicion that the enemy used poisoned missiles.

Thus it was only necessary for Johannes de Vigo, in the commencement of the sixteenth century, to express in dogmatic form the already firmly held views of physicians. "The gunshot wound," said he, "is a contused wound, for the ball is round; it is a burned wound, for the ball is heated; it is a poisoned wound, for the powder is poisonous. The poison is the chief characteristic, therefore the treatment should be directed against that before anything else." And it was on this theory that J. de Vigo stood to decide the fate of gunshot wounds for many years. Among the different forms of treatment most frequently used against the poison was the repeated application of escharotics, *e. g.*, pouring boiling oil into the fresh wounds. Should the topic of discussion at the present time be the treatment of wounds, then it might be said that this historical information was rather far-fetched; nevertheless, the lapse of three and a half centuries is only apparently a long time. The theoretical objection is merely removed, but there remains the undetermined question which Paré sought to explain. We no longer seek the poison in the powder and lead; but, as at that time, we speak of a poisonous effect of the wound on the body; now, as then, this poisonous condition forms the central point of our therapeutical efforts. Indeed, J. Lister's first method of cauterizing fresh wounds with concentrated carbolic acid has certainly much to remind one of the burning-out of gunshot wounds in the citadel of Vallane. That a poisonous substance develops in wounds, or may insinuate itself into them, more especially in gunshot wounds—a substance which has nothing to do with powder and lead—was the next step advanced. Paré himself came to this conclusion.

When he was present with the besieging army before Rouen, many of the wounds became putrid, and the stench arising from them highly offensive. In the bodies of the dead on which autopsies were made, there were found numerous pus infarctions in various organs. The pus was greenish, and the odor very disgusting. Besieger and besieged believed themselves wounded

with poisoned missiles. Paré sought the causes in the contamination of the atmosphere through the accumulation of decaying material, and advised for such cases the scabbing treatment: cauterization with Egyptian ointment, prepared from equal parts of alum, verdigris, and sulphate of copper. Thus he seems to have accepted the doctrine, as it is received to-day, that there is an immediate effect produced on the wound by the vitiated air. The contaminating influence of the air combined with the products of putrefaction, not merely on the wound, but on the organism generally, has never disappeared from the intellectual horizon of physicians. That the mouldering couch of straw, the putrefying bodies of men and animals, the floor and earth saturated with excrement, the overcrowding of badly-ventilated hospitals, give rise to infectious fevers and a bad course to wounds, is not the result of recent observation; also, that it depends on a kind of fermentation, which, by means of the germs contained in the air, is transferred to the body, has become a familiar notion; citing one only of the many authors on this subject, viz., John Pringle, in his *Observations on the Diseases of the Army*, published in 1775, in which he devotes a special chapter to the diseases in consequence of the more putrid air, and his forty-eight experiments on septic and antiseptic substances. This chapter contains experiments similar to those made at the present day, in order to prove the antiputrefactive power of this or that material. Still there remains a vague idea of the nature of substances which excite putrefaction, and they are mostly sought among the gaseous, bad-smelling products of decomposition.[1] Ambrose Paré (1582) first taught that secondary abscesses in surgical cases; which he had observed in the spleen, lungs, liver, and other viscera, "were due to a changed condition of the fluids, produced by some unknown alteration in the atmosphere, and determining a purulent diathesis."[2]

He also recognized the fever which is dependent on the pro-

[1] Volkmann's Sammlung klinischer Vorträge, No. 84 u. 85, s. 639.

[2] Braidwood on "Pyæmia," p. 2.

duction of pus, and classified here, especially that fever which arises between the tenth and fourteenth days after the receipt of an injury, and is ushered in by a chill.[1] The following quotations force the conclusion, that in the early history of medicine there was supposed to be some important relation between wounds of the head and multiple abscesses:—

"Nicolaus Massa (1553) mentions a case of abscess of the left lung, following an injury of the head."[2]

"Valsalva (1707) was induced by his own observations to say that the viscera of the thorax were sometimes affected in wounds of the head."[3]

"Desault (1794) considered abscess of the liver to be a very frequent sequence of head injuries."[4] The fact that wounds of the head were frequently followed by abscesses of the lungs, liver, and other organs, probably led to the opinion expressed by Desault, Barthez, Brodie, W. Phillips, Copland, and others, that the disease had its origin from a nervous agency.

"Bertrandi and Audouillé (1819) sought for a mechanical explanation of the occurrence of hepatic abscesses after head injuries, and in cases of apoplexy."[5]

"Morgagni (1740) somewhat obscurely hinted at the doctrine of the reabsorption of pus—a doctrine which was afterward elaborated by Quesnay in 1819. Morgagni, after quoting a number of instances of wounds of the head followed by visceral abscesses, opposes the idea of a mechanical transport of pus thither, states that such abscesses are not confined to the liver, and that they may follow wounds and ulcers of other parts besides the head. He ascribes their formation to particles of pus (not always deposited in the form of pus) resulting from the softening and suppuration of small tubercles, which, having been mixed with blood and disseminated, are arrested in some of the narrow passages, perhaps of the lymphatic glands, and by obstructing and irritating these, as happens in the produc-

[1] Pitha u. Billroth, Handbuch der Chirurgie, 1 B., 2 A., 1 H., 1 L., 57 S.
[2] Braidwood on "Pyæmia," p. 2.
[3] Ibid. p. 3.
[4] Ibid. p. 5.
[5] Ibid. p. 10.

tion of venereal buboes, and by retaining the humors therein, distend them, and give origin to the generation of a much more copious pus than what is carried thither. 'And by this means,' he says, 'we may also conceive how it is that much more pus is frequently found in the viscera and cavities of the bodies than a small wound could have generated.'"[1]

"Cheston (1776) remarks that 'translations of matter from one part to another are by no means uncommon, but are frequently to be met with after amputations of the larger limbs, when the vis vitæ is impaired, and cannot support that discharge of matter, so necessary to complete the design of nature in healing a large wound; but, under such circumstances, there is very little if any appearance of an inflammation, and the matter is rather disseminated through the viscus on which it falls, than is collected in one or more large vomicæ.'"[2]

"John Hunter (1793), in this country, and after him Velpeau, in France, demonstrated the existence of pus in the blood. Hunter further pointed out the influence and mode of action of phlebitis. He described three forms of inflammation of the veins, viz., adhesive, suppurative, and ulcerative. Pyæmia he considers to be an aggravated form of phlebitis. He remarks that in all cases where inflammation of the veins runs high, or extends itself considerably, it is to be expected that the whole system will be affected."[3] Hodgson (1815) believes in the doctrine of phlebitis, "and affirms that the inflammation extends in some instances even to the membrane which lines the cavity of the heart."[4]

"Arnott (1829) concluded from his observations: 1. That death does not result from the extension of the inflammation of the veins to the heart; 2. That the dangerous consequences of phlebitis have no direct relation to the extent of the vein which is inflamed; and 3. That the presence of pus in the veins, though the principal is not the sole cause of the secondary affection. He accordingly opposes the idea of Abernethy,

[1] Ibid. p. 3.
[2] Ibid. p. 4.
[3] Ibid. p. 4.
[4] Ibid. p. 7.

Carmichael, etc., that the constitutional affection is owing to the extension of the inflammation to the heart. The publication of Arnott's and Dance's treatises led to the general opinion being held in England and France that phlebitis and purulent infection were identical affections; or, at least, that the latter was invariably caused by the former."[1]

"Cruveilhier (1829), admitting the doctrine of the formation of secondary abscesses being due to capillary phlebitis, further laid down an axiom, since proved untenable, 'that any foreign body introduced into the veins, whose elimination by the emunctories is impossible, will produce visceral abscesses similar to those which occur after wouuds and operations, and that these abscesses are the result of capillary phlebitis of those viscera.'[2] Liston (1837), and Bérard (1842), held the phlebitic doctrine. The following authors believed pyæmia to be produced by the admission of pus into the blood, viz: Bœrhaave and Van Swieten (1737), Morgagni (1740), Cheston (1766), Berthelot (1780), John Hunter (1793), Larrey (1812), Montezzia (1813), R. Carmichael (1818), Quesnay (1819), Velpeau (1823 and 1826), Sir Astley Cooper (1827), Maréchal (1828), Dance (1828), Arnott (1829), Piorry (1831), Liston (1837), Dupuytren (1839), Castelnau and Ducrest (1848), Sédillot (1849), Solly (1851), Wilks (1861), and Baker (1866). Haller made the first experiments as to the action of putrefying substances on animals, and said, 'Nothing destroys our fluids more powerfully than putrefaction;' B. Gaspard, Doctor of Medicine in St. Etienne, published the first complete work, founded on abundant experimental material, on the action of putrefying substances on the organism; and since that time (1822) one may look upon the doctrine of septicæmia as established. Leuret and Dupuy followed him; so that in France the doctrine of septic blood-poisoning soon won the ground. Soon, however, the investigators who followed them rejected both the septicæmic and pyæmic conditions, and the effect of the former investigations could have been only unimportant. Ernst R. Virchow, who repeated the experiments of

[1] Ibid. p. 14. [2] Ibid. p. 14.

Gaspard, discriminated with *greater precision* between the surgical diseases—septicæmia as a *sharply defined* group, the opposite of pyæmia. From this date (1848) the difference between septicæmia and pyæmia has been fully established in the literature. . . . . The most important series of experiments conducted, according to Gaspard, belong to Stich (1853), and Panum (1856); the latter endeavoring to separate the putrefying poison. In this, however, neither he nor his followers have succeeded very satisfactorily. These experimenters were followed by Urfrey, Saltzmann, and others. . . . . In 1865–66 the Faculty of Medicine in Munich offered a prize question on the action of putrefying substances on the animal organism, and awarded the prize to Hemmer for his work, which was distinguished for its accurate delineation of the pertaining literature, and the number of prepared experiments. In the mean time Pasteur was making a noise in France by his researches. . . . . Billroth, Roser, and O. Weber published new and valuable works, which considered the observations at the bedside, as well as the experiments."[1]

"Lister, fully appreciating the necessity of protecting wounded surfaces, as far as possible, from the contaminating influences arising from contact with the vitiated air of hospitals, has, by the antiseptic treatment, already accomplished much good. He still adheres to the use of carbolic acid. Binz has proved that a solution of one part of quinine to four hundred parts of water still sufficed with certainty to destroy the life of bacteria. R. Geissler, a few years previously, had mentioned the anti-putrefying property of the salts of quinine, and has used the same as a surgical dressing in carbuncle, cancer, bedsores, etc."[2]

Bergmann, and others, have sought to determine the poisonous substance contained in decomposing animal matter, and for this purpose have chemically treated putrid fluids, hoping to find the agent that would excite all the symptoms of septic poisoning. Bergmann obtained a body of this nature from de-

[1] Pitha u. Billroth, Handbuch der Chirurgie, 1 B., 2. A., 1. H., 1. L., 6. u. 7. S.

[2] Langenbeck, Archiv f. klin. Chirurgie, Band 4, S. 550, 564.

composing yeast, which he calls *sepsin*, although we have no proof that either he or any one else has ever found the same in pus or any decomposing animal substance; and even if it had been found in these substances, it would then become necessary to demonstrate the fact that no other substance contained in putrefying fluids could produce septic poisoning. It has, however, been satisfactorily shown that several substances found in decomposing animal bodies, when injected into the blood, excite septic action.

NOMENCLATURE.—The want of an established nomenclature of pyæmia, and the loose manner in which the terms pyæmia and septicæmia are used by the profession, have doubtless led to much embarrassment.

It will be observed that the early writers on medicine were ignorant of the causes of these diseases, as well as of their pathology. Prior to the publications of Ambrose Paré and Bartholomew Maggi, we find that the diseased conditions now described as pyæmia and septicæmia were supposed to be due to a direct poisonous influence of the powder in cases of gunshot wounds. It appears that the first pathological condition that attracted the attention of the earlier observers was the formation of metastatic abscesses in the lungs, liver, and kidneys. At that time the deposits were usually supposed to arise from the mechanical transport of pus, from wounds on the surface, to the visceral organs. At a later period, John Hunter, and others, supposed pyæmia and phlebitis to be identical diseases; but the more modern writers have used the term "suppurative fever." "Virchow has proposed the name *ichorrhæmia*. O. Weber uses the name *embolhæmia* for the condition in which embolli are found in the blood. The classification given by Hueter, in his excellent work on this subject, appears to me very practical. In pure cases of purulent infection without metastasis he calls the disease 'pyohæmia simplex;' in cases with metastasis, 'pyohæmia multiplex.'"[1] The term hospitalism is used by John Eric Erichsen and Sir James Y. Simpson. The former says:

[1] Billroth, Surgical Pathology, p. 345.

"The overcrowding of wounded people—whether the wound be accidental or surgical matters not—will develop septic disease in one of four forms, viz., hospital gangrene, septicæmia, pyæmia, or erysipelas."[1] And the latter: "The general and acknowledged cause of death after operations in hospitals is some of the forms of surgical fever, as pyæmia, erysipelas, phagedena, etc."[2]

Erichsen further says: "The term pyæmia is used in a very wide and elastic manner, and by many is made to include various forms of blood-poisoning."[3] This remark is especially true of the English writers. Thus G. W. Callender, under the head of "Pyæmia," says: "It signifies little whence these matters are derived, whether from decomposing pus, unhealthy secretions, decomposing hides, dead bodies, vegetable putrefactions, or from animals suffering from acrid discharges, as in glanders; since the influence of all such, regulated by the intensity of the poison, for they vary in this respect, and by predisposing causes presently to be mentioned, may be conveniently described under two modifications."[4] The modifications here referred to are designated as *acute* and *chronic*.

American authors, much more than the English, are inclined to use the term pyæmia in the restricted sense. In fact the German nomenclature has already been adopted in a great measure; and the present indications are, that at no distant day this perplexing question will be finally settled. A correct idea of the sense in which the Germans use this word may be derived from the following extract from Prof. C. Hueter, who says: "If we give to pyæmia at the start, a definite scope, then we must regard suppuration as the *first* and *most necessary condition* for its existence."[5] The above remark is the foundation, and at the same time supplies the boundary, for the use of the term pyæmia by a large majority of German practitioners, although

[1] On Hospitalism (1874), p. 59.
[2] Anæsthesia, Hospitalism, etc., p. 350.
[3] Loc. cit. p. 73.
[4] Holmes's System of Surgery, vol. i. p. 253.
[5] Pitha u. Billroth, Handbuch der Chirurgie, 1. B., 2. A., 1. H., 1. L., 89 S.

Prof. Roser divides the cases of septic blood-poisoning into four classes: "(1) Traumatic sepsis (pure traumatic, primary traumatic sepsis). (2) The poisoning with ichorous pus (secondary infection, self infection). (3) Infection from dissecting wounds and similar material (infected wounds). (4) The specific zymotic septic process (hospital gangrene, carbuncle, cancer, etc.).

Stromeyer furnishes the following classification, viz: (1) A very rapid decomposition of the blood prior to the commencement of suppuration. (2) Acute pyæmia with the commencement of suppuration. (3) Subacute pyæmia. (4) Chronic pyæmia."[1]

It will be observed that Stromeyer's classification does not differ materially from the one ordinarily used. The first order refers to septicæmia, while the second, third, and fourth indicate the varieties of pyæmia.

Roser's classification is intended to cover all cases of septic blood-poisoning, which may truly be viewed as a single chain composed of many links. Take, for example, a case of amputation of the thigh, followed in a few hours by traumatic fever, later by septicæmia; afterwards there may develop secondary fever, formation of ichorous pus with absorption, and its concomitants, pyæmia, accompanied by thrombosis, embolism, abscesses in the lungs, liver, etc. To these may also occasionally be added phlebitis, and inflammation of the joints, terminating speedily in suppuration. The chain may in this case be further lengthened or varied, with traumatic erysipelas, hospital gangrene, etc. In fact, the variations in these cases are very numerous, and all these conditions, together with many others, are due to septic blood-poisoning. The nomenclature of septicæmia requires little attention here, although now and then we find the terms "septic fever" or "putrid fever" used in its place.

PATHOLOGY.—The study of the pathology of pyæmia may be advanced by adopting Hueter's classification, which is based on recognized post-mortem lesions, and designated pyæmia simplex and pyæmia multiplex. The pathological appearances in these

[1] Pitha u. Billroth, Handbuch der Chirurgie, 1. B., 2. A., 1. H., 1. L., 40. S.

forms of the disease differ widely, although the clinical symptoms are often similar. In pyæmia simplex the pathological conditions are essentially negative. This variety can only destroy life by the height and duration of the fever, which is maintained by the absorption of the fluid or molecular elements of pus. There is often found, as an essential basis of this form of the disease, extensive suppuration in the subcutaneous or sub-facial tissues. We are not able to demonstrate the pyrogenous substance in the blood, since its chemical composition is unknown. It is supposed that possibly the pyrogenous material finds its admission into the blood with the pus-corpuscles, but still it remains to be proved that pus-corpuscles are thus admitted. The arguments in favor of the admission of the pus-corpuscles into the blood are as follows: 1. The blood in pyæmia is known to contain more white granular spherical bodies than are normal. The question has been raised, are they pus-cells, or white blood-corpuscles? The answer is difficult, and has not yet been attained. Virchow, in the mean time, has proved that we cannot differentiate, morphologically, between blood and pus-corpuscles. 2. Cohnheim has demonstrated the existence of the wandering corpuscles in cases of inflammation. Therefore it appears probable that in cases of pyæmia the blood may contain the pus-corpuscles, but further investigation is needed to establish the fact. However, the establishment of this point would still leave the more important one undetermined. Billroth supposes that the pyrogenous substance exists in connection with the pus-corpuscles; but this may be justly questioned after the experiments of O. Weber and Frese. These experiments consisted in carefully filtering pus and then injecting the filtrate into healthy animals. It was found that these injections were uniformly followed by a marked increase in the temperature. Therefore, these investigators supposed that the pyrogenous elements of the pus are contained, at least in part, in its serum. There are other important changes observed in the blood of patients dead of pyæmia, to which I now desire to direct attention. The red corpuscles of the blood, even in the early stage of the disease, in many cases show signs

of disintegrating into molecules, and are observed to be accumulated into masses without showing the slightest tendency to form rouleaux. There is a steady increase in the number of pus or white blood-corpuscles in the blood of pyæmic patients, during the whole course of the disease in fatal cases. The condition of the red corpuscles, already mentioned, becomes more and more marked toward the fatal termination. In all cases of pyæmia multiplex the increased coagulability of the blood may be observed in the early stages of the disease, which steadily increases as the disease progresses. In pyæmia simplex this condition is less marked, although generally present; while, *e. g.*, we know septic poison diminishes or destroys the coagulability of the blood. Hereby the possibility is given, at least on the cadaver, to differentiate between pyæmia simplex and septicæmia; if, in the mean time, the study of the pathology of septicæmia was prosecuted even by comparison, since cases occur of the more fatal septic infection, in which the *post-mortem* conditions are a complete or almost complete negative. Therefore the differential diagnosis on the cadaver must be limited to this, that we are able to demonstrate the existence of a purulent or ichorous deposit."[1]

It will be readily observed that the differential diagnosis mentioned above relates to pyæmia and septicæmia, and not to the different varieties of the former disease. The following facts should be kept constantly in mind by the surgeon, to enable him to differentiate between the two forms of pyæmia. In pure cases of purulent infection without metastasis, the disease is called pyæmia simplex; and in cases with metastasis, pyæmia multiplex. The various conditions on which the metastasis may depend are shown by Hueter, who says: "The metastatic abscesses of pyæmia multiplex met with in the lungs, liver, spleen, and other internal organs are regarded with the greatest possibility, as a result of the embolic process. The metastatic inflammation of the serous membranes, of the cellular tissues, and of the parotid glands, and probably also a few metastatic

[1] Pitha u. Billroth, Handbuch der Chirurgie, 1. B., 2. A., 1. H., 1. L., 70. S.

inflammations of the internal organs, are at present supposed to arise from a general inflammatory diathesis."[1]

It has already been shown, by numerous experiments on animals, that metastatic abscesses in the lungs, liver, and other visceral organs only arise after the introduction of ichorous pus, while healthy pus has uniformly failed to produce this result. I shall take occasion to refer to this subject more fully under the "Etiology of Pyæmia." It now remains to be shown how the introduction of ichorous pus acts in the production of pyæmia multiplex. The ichorous pus having found its way into the venous circulation, gives rise to the formation of thrombi in the veins; these clots become more or less broken up, and are carried forward by the blood to the right auricle; from this auricle to the right ventricle; from this ventricle to the pulmonary artery, and through its ramifications to every part of the lungs. In the minute ramifications of this vessel are found wedge-shaped clots of various sizes, in different conditions, some softened and others still firm. The possibility of these clots ever passing through the lungs, and afterward being arrested in other visceral organs, has been demonstrated on animals. It has been shown that fine particles of foreign matter, injected into the veins have passed through the lungs, and subsequently lodged in the liver. This theory enables us to account for the existence of metastatic abscesses in the liver, which have apparently originated as the result of primary infection, but thus far only on a mechanical basis. In other cases these abscesses are supposed to arise from secondary infection. Thus ichorous pus, having found its way into the venous circulation, produces primarily venous thrombi, which, as in the other instances, break up, the clots being carried in the same manner into the terminal branches of the pulmonary artery, where they are designated as emboli. The first action of the emboli is the mechanical closure of these vessels, thus depriving the surrounding parts of nutrition, to a greater or less extent. It will be proper now to recall the fact that the composition of these em-

[1] Pitha u. Billroth, Handbuch der Chirurgie, 1. B., 2. A., 1. H., 1. L., 88. S.

boli is such as to favor rapid suppuration; this commonly commences in the clot and surrounding tissues, having been preceded by a brief stage of congestion and inflammation. There is also occasionally found around these points more or less extravasation. The metastatic abscess thus found in the luugs is favorably situated for the production of secondary infection. From this abscess thrombi arise in the pulmonary veins, which become disintegrated, and are carried to the auricle, thence to the left ventricle, and finally through the aorta, and find lodgment in the terminal branches of the arteries of the various organs, where they produce the characteristic trouble. The organs that most frequently become the seat of this secondary infection are the liver, spleen, kidneys, brain, and eyes.

Let us now briefly examine this mechanical theory. Do metastatic abscesses arise from a single cause or from a combination of causes? I am inclined to the opinion that the proximal cause of metastatic abscesses in the visceral organs is the existence of emboli in the terminal branches of arteries. The vitiated atmosphere surrounding the patient, the existence of a wound, and the formation of ichorous pus, are conditions which should not be lost sight of. These are the elements acting on the blood, producing in it morbid changes, and may, therefore, be regarded as the predisposing causes. The morbid condition of the blood, the increased number of white blood-corpuscles (possibly pus), the disintegration and other changes in the red corpuscles, may be regarded as the exciting causes of metastatic abscesses. It is thus readily observed that emboli may form in the lungs and liver at the same time, or the origin of those in the lungs may precede the formation in other organs. Again, the formations may be limited to a single or exist in several organs at the same time. Is the formation of emboli in the terminal branches of arteries always dependent on the disintegration of thrombi? The answer to this question must, I think, be a negative, although in surgical practice it rarely happens that an embolus takes its origin from any other cause. In the large majority of cases, unquestionably, the thrombi primarily exist in the vicinity of the wound in which

the ichorous pus is generated; but it not unfrequently happens, during the process of disintegration, that broken-up clots are carried forward by the current of blood, receiving accretions on the way, until finally they fill a large venous trunk. In confirmation of these facts relating to the primary origin of thrombi, it is said to have been observed, in epidemics of "puerperal fever," which were complicated with metastatic abscesses of the visceral organs, that the thrombi occurred in the pelvic veins. In case of wounds of the lower extremity the clot is frequently found in the common iliac vein, although probably it should always be regarded as a secondary formation. In rare cases the only thrombi discovered at the autopsy are found situated far away from the injury. Billroth records the case of a young woman who died of phlegmonous erysipelas of the lower extremities, where thrombi were only found in the brain. Observation fully establishes the fact that pathological changes are much more frequently met with in the lungs than in any of the other organs of patients dead of pyæmia. This certainly strengthens the embolic theory. Billroth mentions eighty-three cases of true pyæmia multiplex in which the metastatic abscesses occurred as follows: seventy-five times in the lungs, seventeen times in the spleen, eight times in the liver, and four times in the kidneys.

"Prof. Sedillot, of Strasburg, who has studied this disease with great care, and who has combined the results of his observation in a highly instructive and interesting monograph, published in 1849, remarks that in one hundred cases of pyæmia, we should find the lungs affected in ninety-nine, the liver and spleen in one of twelve, the muscles in one of fifteen, and the heart and peripheric cellular tissue in one of twenty; the brain and kidneys are comparatively seldom involved."[1]

The theory previously mentioned as the embolic relates to the aggregation of the fibrin into clots; but another theory has been recently advanced by E. Wagner, who "found in many cases the capillaries in the lungs filled with fat, and was inclined,

[1] Gross, System of Surgery, vol. i. p. 150.

from the direction it extended in these vessels, to explain a certain number of the pyæmic cases by the fat-emboli. Here arose the necessity for the experimental examinations of this question, which were soon undertaken by different parties. As still further pathological observations followed these experiments, so rose over the question of fat-emboli an extensive literature, to the analysis of which I cannot now give my attention. This condition is not very rare, especially after severe injuries of bones; and the medullary substance appears to be the most frequent source of the fat-emboli, although the fatty connective tissue, the collection of fat-drops in venous thrombi, etc., are also to be taken into consideration. The easiest method to produce the fat-emboli experimentally is by crushing a medullary cavity in animals, or otherwise by the direct introduction of fluid fat into the veins. We have satisfied ourselves by such experiments, that fat-emboli destroy life only when the occlusions of the capillaries of the lungs are very numerous, and when the act of respiration is thereby greatly disturbed. Insignificant fat-emboli are easily borne. The existence of fat-emboli in pyæmia is therefore purely accidental, and has no characteristic significance. Multiple pyæmia very frequently occurs without fat-emboli and *vice versa;* either process may complicate the other, and so the fat-emboli may acquire special importance by obstructing the respiration, and probably also in this manner the embolic fat may serve as a carrier of a putrid and phlogogenous material."[1]

Having already examined the theories pertaining to the various forms of pyæmia, and the general characteristic of this disease, as well as of septicæmia, we are now prepared to begin with the *port-mortem appearances of pyæmia multiplex.*

General Appearance of the Body.—Rigor mortis, commonly well marked a few hours after death; great emaciation and other important changes, rendering the appearance of the body repulsive and sometimes hideous.

[1] Pitha u. Billroth, Handbuch der Chirurgie, 1. B., 2. A., 1. H., 1. L., 88. u. 89. S.

Skin and Cellular Tissue.—The integument is flabby, pale, or occasionally of a deep icteric hue; sometimes sudamina, circumscribed ecchymoses, pustular eruption, irregular spots of a dusky color, gangrenous patches, etc. The cellular tissue in some cases is the seat of diffuse suppuration. The pus formed is generally thin, fetid, and unhealthy. This suppuration may be limited to certain parts of the body, as an injured extremity, or, as frequently happens, it may be found on the trunk and limbs at the same time. The pus in this form of suppuration is exceedingly apt to burrow, on account of the peculiarities of the tissues in which it occurs, and also the condition of the surrounding structures, especially the relaxed and flabby condition of the skin. These abscesses are in some instances superficial, in others deep-seated. The edges of the wound, after death, are of a blackish-green color, frequently showing evidences of the separation of a recent slough. The surface is usually dry, but may be covered with foul pus.

Muscles.—There are few changes which occur in the muscles, and none are uniform or constant. They are occasionally the seat of abscesses, and these have been observed in the heart, tongue, and other organs. They may be of a light-brown or greenish color, when they have been covered for a considerable time with pus, and are sometimes softened and pultaceous. Suppuration does occasionally take place beneath the fascia of the tendons.

Brain and its Membranes.—Neither the brain nor its membranes are constantly the seat of pathological changes, although congestion of one or more of its membranes is by no means rare, "particularly where death has been preceded by great dyspnœa."[1] Occasionally there have been observed suppurative meningitis, engorgement of the venous sinuses, blood extravasations on the surface of the brain, lymph-deposits on the membranes, softening of the cerebral tissues, circumscribed abscesses in the substance of the brain, which in some cases have been traceable to embolism of its vessels. The fluids in

[1] Pitha u. Billroth, Handbuch der Chirurgie, 70 S.

the ventricles may be either diminished or increased, and very rarely are found mixed with pus. The changes in the spinal cord and its membranes probably are similar to those found in the brain, but appear to have been rarely examined.

Eyes.—"H. Meckel first called attention to the fact that examinations of the eye in persons who died of pyæmia, which is certainly rarely enough performed, might lead to the discovery of pyæmic ophthalmia. Virchow found, in a few such cases, emboli of the retinal and choroidal vessels. Probably this would be proved correct by more industrious examinations of the eye, that these conditions are somewhat less seldom than until now had been supposed."[1] Arnott thus describes this affection of the eye: "There is redness of the conjunctiva, intolerance of light, and contracted pupil, rapidly followed by opacity of the cornea, and excessive chemosis. The eye ultimately sloughs, and its contents escape."[2]

Ears.—"The late Mr. Toynbee, in his admirable treatise on 'Diseases of the Ear,' relates several cases of 'purulent infection,' following suppuration in the ear. 'Cases of diseases in the mastoid cells terminate fatally,' he says, 'from two different causes: first, from purulent infection, arising from the introduction of pus into the circulation through the lateral sinus; second, from disease of the cerebellum or its membranes. Cases of purulent infection,' he further remarks, 'have not been met with when the disease occurs in the tympanic cavity.'"[3]

Bones.—There are numerous changes, in pyæmic cases, occurring in the bones, probably from the fact that pyæmia results very frequently in cases of bone lesions, but these changes have very little diagnostic importance. The following have been observed: "thickening, absence, or infiltration of the periosteum, which may be found to separate readily from the bone after the death of the patient; or there may be pus found between the periosteum and the bone. In the bone structure there are found caries and necrosis," "while in other cases the whole thickness

[1] Ibid. 71 S.
[2] Braidwood on Pyæmia, pp. 168, 169.
[3] Ibid.

of the 'compact' tissue is perforated in a honey-comb like manner by minute cavities, filled with a thickish pus, or caseous matter of a pinkish-white color." "To sum up, the chief morbid alterations met with in the bones are congestion, dilatation of the Haversian canals, and the cancellated tissue, leading to abscess formation, and the excavation of cavities by the unhealthy pus."

Joints.—The pathological lesions of the joints commence with marked congestion of the synovial membranes, increase of the synovial fluid, and afterward the fluid is mixed with pus; these conditions are followed by erosion of the cartilage and ligaments, the former thus becoming separated from the bone. Both the large and small joints are occasionally the seat of morbid changes.

The Glandular System.—Lymphatic glands are only secondarily affected in pyæmia, and even this takes place very rarely. The changes when observed are similar to those which happen in other tissues of the body, viz., congestion, inflammation, and suppuration.

Blood.—The changes in the blood have been so fully detailed in other portions of this article, that it is now thought unnecessary to enter again on the subject. The arteries are usually found empty after death from this disease, and the coats are sometimes apparently thickened. The veins are commonly found, on the contrary, filled, or even distended, with firm fibrinous clots. They are also sometimes found inflamed or altered, although commonly healthy. The distended condition of the veins gives rise to the cord-like feeling often mentioned by different observers. In some cases of phlebitis there may be pus deposited between the coats of these veins. The thrombi are occasionally observed as firm fibrinous clots, but they are frequently found, in the rapidly fatal cases to have undergone suppurative changes. These changes begin in the centre of the clots, which often contain true pus, or a greenish puriform fluid.

Pericardium and Pleuræ.—The pericardium occasionally contains a small amount of serum tinged with blood, but it is rarely

covered with recent lymph. "The pleuræ are generally inflamed in this disease, along with the pulmonary tissue proper. The costal and visceral layers are sometimes found firmly, even inseparably, agglutinated together by old adhesions. They are, however, more commonly united by recently-formed lymph, which covers more or less of their extent, and is easily broken down. Occasionally both sides of the chest, but generally only one, is the seat of this inflammatory process. The pleural cavities commonly contain some opaque, muddy, sero-purulent fluid mixed with blood and having masses of lymph floating in it."

Lungs.—It has already been shown that the lungs, much more frequently than the other organs, are the seat of metastatic abscesses and other morbid changes in pyæmia multiplex. The theories of their formation and frequency are in complete accord. The following is a summary of the morbid changes in these organs:—

Emboli in the branches of the pulmonary veins, metastatic abscesses surrounded with capillary congestion, and other evidences of inflammation. "The smaller vessels, trying to overcome this afflux of blood, may produce ecchymoses or extravasations beneath the lining membrane of the air-vesicles; but these minute capillary congestions are generally observed as red points studded over the pulmonary surface, which by and by exhibit yellowish-white or bluish-white centres. While one part, generally the lower half of the lung, is thus hepatized, solid, and of a dark greenish color, the remainder of the lung is emphysematous, and more or less œdematous. A section of the former presents the same appearance as is observed in the lungs of pneumonic patients. Whether these incipient abscesses are developed from the minute point of congestion aforementioned by the breaking down of some thrombic clot in their centres, or whether the pus is developed out of the serum exuded by the walls of the engorged capillaries, cannot be easily determined, and has, as yet, not been decided. These secondary abscesses vary in size from that of a hemp-seed to that of a hen's egg." These are generally situated on the periphery of the lungs and

in the lower lobe, although in some cases they are found imbedded deeply in the pulmonary tissue. The contents of these abscesses are similar to those found in abscesses of other parts of the body in this disease. The bronchial mucous membrane is commonly of a bright pink color, while its secretion is increased in quantity, and may be clear and frothy. These conditions in this membrane are the result of acute bronchial catarrh. The peritoneal cavity may contain an increased quantity of clear or cloudy fluid.

Spleen, Liver, and Kidneys.—Billroth and Sédillot observed pathological lesions involving a solution of continuity in these organs, in the order in which they are mentioned above; other authors, however, assert that the liver, next to the lungs, is the most frequent seat of purulent deposits. Enlargement of the spleen is frequently met with in cases of pyæmia multiplex. The metastatic abscesses found in the spleen and kidneys are much smaller than those found in the lungs and liver, but in other respects are of a similar character. The capillary congestion and the accompanying infarctions require no special attention here. The liver like the spleen is sometimes enlarged, and at other times is found to have undergone fatty degeneration to a greater or less degree, in which condition its tissues are generally soft and friable. Abscesses in the liver are so much like those in the lungs as to need no separate description. The same may be said of the other pathological changes found in this organ in pyæmia multiplex. The abscesses found in the kidneys vary from the size of a hemp seed to that of a bean, and are surrounded by the usual zone, marking more or less definitely the extent of the inflammation. The capsule is generally healthy. There are, also, in very rare cases of this disease, abscesses found in the stomach and intestines, involving the thickness of the mucous membrane; and it is further supposed that these abscesses may be found occasionally on any portion of the mucous membrane lining the alimentary canal. *Post-mortem* examinations in cases of pyæmia multiplex have established the fact that there is no organ in the body but what may become the seat of the pathological lesions in this disease;

but there is unquestionably a vast difference in the relative frequency of these changes in the various organs. It is now readily observed that the pathological lesions in pyæmia multiplex are so positive as to render further discussion of the subject unnecessary.

Pyæmia simplex may be readily mistaken for septicæmia and *vice versa*. In both conditions the pathological appearances are occasionally nearly or completely negative. "The *materies morbi* occasionally induce death ere the local lesions have had time to manifest themselves."[1]

I shall now attempt to point out the pathological peculiarities pertaining to each of these diseases, and also mention the important difference in origin, for the purpose of aiding in the determination of the differential diagnosis on the cadaver. I must, therefore, call attention to the fact that *pure septicæmia* is a disease which owes its origin to the absorption of *septic not purulent matter*. In all cases where there is absorption of septic and purulent matter, the disease is properly called septo-pyæmia; and should the autopsy reveal the presence of metastatic abscesses, then we would immediately recognize the fact that there had been an absorption of ichorous pus and septic matter; while the non-existence of metastatic abscesses, under somewhat similar circumstances, would certainly imply the absorption of non-ichorous pus and septic matter. Pus is often rendered ichorous by the action of the atmosphere; therefore, the pus exposed to this action may be regarded as possessing the power of producing metastatic abscesses. In other cases there may be extensive suppuration while the pus does not at any point come in contact with the air, and here the purulent absorption would fail to produce these peculiar lesions—metastatic abscesses—but might produce pyæmia simplex. This subject is further explained under the "Etiology of Pyæmia." The question now arises: How soon after the receipt of an injury, or the performance of an operation, may pus form? Hueter, who has given much time and attention to the study of pyæmia and

[1] Braidwood on Pyæmia, p. 164.

septicæmia, and who certainly has written the best monograph on this subject ever published in any language, thinks the formation of pus must require four or five days. It, therefore, becomes probable that in all cases of blood-poisoning before the lapse of that time, the case is one of pure, unmixed septicæmia; after the lapse of this period there is always a possibility that the case is one of septo-pyæmia. We have previously mentioned the fact that septic poison diminishes or destroys the coagulability of the blood. Here is the important point in our differential diagnosis on the cadaver. In septicæmia there is at least *diminished* coagulability of the blood. In pyæmia simplex, generally, there is *increased* coagulability with the other changes already noted.

Pyæmia simplex must take its origin from the development of pus in the patient's body, or the pus must certainly be brought in contact with a wounded surface. The existence of suppuration in any portion of the patient's body would certainly render doubtful the diagnosis of pure septicæmia. In pure septicæmia there are no purulent deposits to be found on the cadaver. In pyæmia simplex there is a purulent deposit or deposits, but these are generally excluded from the atmosphere. In both forms of pyæmia there are purulent deposits, or at least there must be evidence of suppuration having taken place.

ETIOLOGY. 1. *Pyæmia.*—It is said by Billroth that "the term septicæmia essentially depends on the etiology,"[1] and the same remark would apply with equal force to the term pyæmia. The latter term was first used by Piorry, and the disease is supposed to be due to the absorption of pus, or its constituents, into the blood. In fact, if we use the term pyæmia in the restricted sense in which it is now commonly employed by German and American authors, then it may be safely asserted that the origin of the disease has been *fully demonstrated* by an almost unlimited number of experiments. That pus, or some of its elements, produces this condition, is not denied by any observer; but there are many disputed points bearing on this question,

[1] Surgical Pathology, p. 336.

and I regret that, for the present, I shall be obliged to limit myself by merely mentioning the same without giving either the experiments or arguments relating to them.

The injection of pus into living animals produces local, remote, and constitutional symptoms. The character of these symptoms depends largely on the kind of pus, laudable or ichorous, the quantity injected, and the site of the injection. It will readily be perceived that, in cases where the pus is directly thrown into a vein, the local symptoms would be unimportant, while the danger of remote trouble—metastatic abscesses in the lungs, liver, etc.—would be very great; but, should the injection be made into the connective tissue, then the relations would be reversed. Constitutional symptoms may exist in both cases, but will differ in character and degree. In regard to the character of the pus, and its agency in the production of this disease, Billroth says: "The old view, that pyæmia is only induced when decomposed pus (ichor) is reabsorbed, is entirely erroneous. There are cases where decomposed putrid pus enters the blood, and which present a combination of the symptoms of septicæmia and pyæmia (septo-pyæmia of Hueter)."

Dupuytren failed to produce metastasis by injections of pus into the veins of dogs; these results were confirmed by Boyer, who only obtained metastasis when he used ichorous pus in his experiments. The same results are recorded in the works of Gunther and Sédillot, based on numerous experiments. Beck made fourteen experiments, very carefully, but did not succeed in producing metastasis in a single case. The same results are recorded by a commission of the Physiological Society of Edinburgh. O. Weber has recently shown, by extended experiments, that carefully filtered pus will not produce metatastic abscesses in the lungs. Therefore it may be considered as proved that *fluid pus injected into the veins of an animal produces no metastatic point of inflammation.* It should not be supposed, however, that because injections of fresh (non-ichorous) pus failed to produce metastatic abscesses, it was therefore without results, as the earlier experimenters thought. Billroth and O. Weber have shown, by their recent experiments, that these injections are uniformly

followed by fever, and if subcutaneous, by abscess; and further, that injections of fresh pus produce even a higher temperature than the ichorous; but the pus taken from cold abscesses has apparently very slight effects. The fresh, non-ichorous, dried pus was found to possess in a similar degree the power to excite inflammation and suppuration; even the removal of the albumen did not change its character or power. It will be observed that these injections caused not only local inflammation, but severe constitutional symptoms, as high temperature, etc. Unfortunately, thus far all the experiments made have completely failed to show the agent that excites the inflammation, although it is generally admitted that it exists, at least, in the molecular bodies. Virchow and Panum have shown conclusively, by their experiments on living animals, that the introduction of foreign bodies into veins—as powdered coal, wax-balls, and quicksilver—fail in all cases to produce metastatic abscesses in the visceral organs, or other symptoms of pyæmia. These foreign bodies were frequently found blocking up the terminal branches of the pulmonary artery, in some cases encapsuled; frequently resembling miliary tubercles, and occasionally surrounded by evidences of slight local inflammation, but in every instance without suppuration. The same experimenters, however, observed that the introduction of ichorous pus and decomposing animal tissue into the veins was attended with the formation of metastatic abscesses and other symptoms of pyæmia. They therefore conclude that the introduction of putrid animal substances into the veins and the further transport of the same to the branches of the pulmonary artery, produce metastatic abscesses, and that the origin of these deposits is independent of the mere stopping up of the branches of this artery. The occlusion of the bloodvessels in this diseased condition is a subject which has given rise to much discussion.

Some of the earlier writers supposed this phenomenon constituted the disease pyæmia, while others believed it to be the essential cause. Prof. Roser says: "But the thrombus is, as can be easily proved, not the cause but only a symptom of pyæmia. If a surgical patient, *e. g.*, one suffering with an injury

of the head, is attacked by inflammation and occlusion of a large vein, perhaps the common iliac, then there are three different theories for the inflammation of the occluded vein, viz., Hunter's, Rokitansky's, and Virchow's. According to the old Hunterian phlebitic theory, the coagulation of blood should be a result of the inflammation of the vein. On account of the circumstances under which the coagulation in the vein should have occurred, one represents that the cause must be an oozing of coagulable exudation from the inflamed walls of the vein. But pathological dissections, especially Rokitansky's, would not accord with it. Large veins were found plugged up without the existence of corresponding indications of inflammation, and frequently perfectly clear indications that occlusion preceded the inflammation. Consequently the occlusion of the vein was the primary condition, and this must be explained in some other way than by its inflammation. Rokitansky, in his theory, recognized an independent disease of the blood.

Certainly, had these diseased conditions of the blood been examined into, it would have supplied no theory for the explanation of the preceding facts. If it is recognized as correct that a primary disease of the blood is to be admitted, yet the coagulation of the blood in a large vein has not been traced back to it. It remained wholly unexplained why a single vein, especially one so large and strong as the common iliac, should become the seat of the local coagulation. The necessity of finding a local basis for the local coagulation could not be denied. For that reason it was greeted as a highly desirable advance when Virchow[1] pointed out that the occlusion of such large veins could be dependent on the coagulation of the blood in the concave spaces behind the valves of the veins, or through the coagulation in the small branches, *e. g.*, the hypogastric vein, which is gradually carried forward until it reaches the common iliac, and by the continual increase this vein also may be filled up. At the same time it was demonstrated that not unfrequently, much oftener than was formerly supposed, the coagu-

[1] Archiv der Heilkunde, erst. Jahrg., erst. Heft., S. 43

lated masses of blood are broken up and carried further on in the circulation, in this manner producing occlusion of the pulmonary artery or its branches. The examination of this subject finally brings Prof. Roser to this conclusion: "Contamination of the blood is essentially the primary cause of pyæmia; thrombosis is only a result of this morbid contamination, and cannot, therefore, be regarded as the cause of pyæmia, but only as an apparent part, as one of the symptoms of the same."

The opinion here expressed by Prof. Roser I believe to be the one generally entertained by the profession at this time. This fact being admitted, the most important question presenting itself for our examination is, How is this contamination of the blood produced? A complete investigation of this subject would require the presentation of the entire subject of "Disease Germs; their Nature and Origin." I shall not venture to enter on this disputed field, but shall confine myself strictly to that form of the disease arising from, or associated with, traumatic injuries. In these cases surgeons recognize two principal sources of contamination of the blood, viz., the wound itself and the vitiated condition of the atmosphere surrounding the patient; contamination in the first place directly from the wound through the bloodvessels; and in the second, by the passage of disease-germs, or the poisonous elements, into the blood along the respiratory tract. These germs may be generated in the wound, or be received into it from the surrounding atmosphere. The character of the wound and the conditions surrounding the patient thus become important subjects for the consideration of the surgeon. It has been observed, and is now generally admitted, that those wounds complicated with a fracture of the long bones of the extremities, opening large medullary cavities and extensive lesions of the soft parts, always increase the danger of blood-poisoning. This fact may be more thoroughly understood by a brief consideration of the condition of the parts. Frequently, in open fractures, large quantities of pus constantly remain in contact with the surface of the wound, while detached fragments of bone speedily become necrosed, moving about with every motion of the injured limb, lacerating more or less the surrounding tissues, and thus

exciting inflammation and suppuration. The periosteum becomes inflamed, a widespread *suppurative periostitis* is the result; necrosis of the bone, from insufficient nutrition, follows, while mechanical pressure on the pus aids in its absorption. The medulla frequently takes on this suppurative inflammation, and here the surgeon fails to receive a prompt warning of danger; slowly the suppuration progresses, without pain or other symptoms, unless the disease has extended to the other tissues; the medullary cavity, at the fractured end of the bone, may be completely or partially occluded by a new osseous formation; in such cases the absorption of pus by the comparatively large venous vessels of this cavity is greatly facilitated. The soft parts also may be the seat of dangerous trouble. The same force that produced the wound and fracture may also have contused the soft parts, destroying in a greater or less degree their nutrition, thus giving rise to gangrenous sloughs, or in other cases to the formation of abscesses, etc. I will also call attention to the fact that the laudable pus in these cases is most favorably situtated for a rapid change into that commonly called putrid. The heat of the parts and the contact of the pus with the atmosphere will not fail to effect its rapid decomposition.

The question may be with propriety asked here, Is fatal pyæmia, independent of a wound, produced by breathing vitiated air? The answer to this question must generally be a negative, although it is certainly true that poisoning of the blood does take place to a certain degree, as is abundantly shown by the different symptoms arising in patients thus exposed who are not suffering with wounds. It is said that dogs exposed in this way are found to rapidly emaciate and suffer from severe and constant diarrhœa. The various symptoms arising in patients confined in the overcrowded and pus-infected wards, among which may be mentioned loss of appetite with diarrhœa and emaciation, are too well known to require an enumeration here. Therefore it appears highly probable that living in and breathing a vitiated atmosphere may act as a strongly *predisposing cause*, only requiring a slight scratch or abrasion of the skin, in which the infection may be said to act

as an exciting cause to produce pyæmia. In reference to such complications the following questions are asked by Prof. Roser: "Is it a specific deleterious material, a miasmatic or contagious disease-poison, or, as it is generally expressed, a zymotic agent? Must we regard each particular typhus-like fever, with its remarkable changes of the blood, with its various localizations in all the organs and membranes, with its chill, furred tongue, petechia, delirium, etc., as we regard typhus, scarlatina, variola, etc.? or as Virchow teaches us, is this pyæmia, so greatly feared by all surgeons, only an ontological idea? Is the word pyæmia only a general name for three different conditions, viz., leucocythæmia, thrombosis, and embolism, or icorrhæmia and septicæmia? or are there, as many have supposed, two ways in which pyæmia may originate? Is there one primary miasmatic pyæmia analogous to the other epidemic, so-called zymotic diseases? and again, a secondary pyæmia arising from suppurative inflammation wherein the poison is formed in the patient's own body which is infected by a single organ?"[1] That this disease is caused by a *specific deleterious material*, in the large majority of cases, is no longer a question for discussion. The only question to consider is, whether it *always* arises from this cause. We must necessarily admit that so-called spontaneous cases do occur, especially if we include in our classification of pyæmia puerperal fever and erysipelas. Are there really any cases of sporadic origin, or are they always due to endemic or contagious influences? No definite answer can be given to these questions, although undeniably the weight of argument is opposed to a sporadic origin.

The term miasmatic, as used by Prof. Roser, probably refers to the vitiated condition of the atmosphere, as seen in the overcrowded surgical and obstetrical wards of the hospitals. In no other sense can the word be appropriately used in connection with the subject of pyæmia. It is true that pyæmic diseases are found to prevail at certain seasons and in certain localities much more extensively than under other circumstances. The

[1] Archiv der Heilkunde, erst. Jahrg., erst. Heft, S. 39.

same however is true of cholera, typhus fever, scarlatina, variola, and other contagious diseases. That pyæmia is contagious has been frequently demonstrated. I therefore conclude that the prevalence and spread of this disease must be explained by the same rules as are applied to the existence and propagation of these allied affections.

2. *Septicæmia.*—The etiology of septicæmia primarily involves two essential facts, viz: (*a*) the development of putrid poison, and (*b*) its reception into the blood. That the origin of this disease may be more easily understood, it may be advantageous to examine the circumstances under which it too frequently occurs. Take, for example, a patient who has received a compound comminuted fracture of the leg, necessitating amputation of the thigh. The amputation is performed a few hours after the injury; the flaps are closed, after which some oozing takes place which is mechanically retained within the flaps, where the warmth of the parts and the presence of the atmosphere are favorable conditions for a rapid decomposition of this effused blood. Here we have a very rapid formation of the putrid poison, and further examination shows a condition highly favorable to its speedy absorption. It is a fact recognized by all surgeons that opening the medullary cavities of long bones is an invitation to the putrid poison to enter the circulation: but here we find not only an invitation, but compulsion, in the form of pressure. The flaps are nicely approximated, this approximation aided by sutures and straps of adhesive plaster, conditions facilitating the agglutination of the lips of the wound which speedily follows. Other conditions which undoubtedly act as predisposing causes are, a fresh wound and the lowered vitality of the patients due to loss of blood, shock, etc. In reference to the former condition, "C. Busch has shown by experiments on animals that a rapid absorption of colored oil, which as a test he injected into the medullary cavities, took place in the lymph and blood-vessels."[1]

Cases answering the above description are still occasionally

[1] Pitha und Billroth, Handbuch der Chirurgie, 1. B., 2. A., 1. H., 1. L., 28 S.

seen, and should septicæmia fail to develop within forty-eight hours, it certainly could not be attributed to good surgery. Probably it is very rarely the case that all, or even a majority of the conditions detailed above, are present, but they exist in a modified form; for instance, they frequently occur in cases of compound fracture of the long bones, with or without contusion of the soft parts, or without extravasation into the cellular tissue, during an effort to save the limb. This putrid poison, the existence of which in the blood is a *conditio sine qua non* for the production of septicæmia, is supposed to act as a ferment in the blood, so deteriorating it that it cannot perform its physiological functions. The disease may be induced in animals at any time by the injection of putrid animal or vegetable substances, and Hemmer declares in regard to the intensity of its action that it can only be compared with woorara and the poisonous bites of snakes. Further, other experimenters have shown that the intensity of action principally depends on the quantity of poison introduced into the circulation; hence injections made into the connective tissue are less fatal than those directly into the veins. Granulating wounds may be with impunity covered with putrid substances as long as the granulations are not destroyed. Healthy integument and mucous membranes resist the absorption of putrid materials, while, on the contrary, fresh wounds permit absorption to take place readily, and it may be greatly facilitated by pressure. The question has been frequently discussed, in relation to pyæmia and septicæmia, whether molecular bodies ever sufficiently enter the circulation through the healthy tissues to act as ferments in the blood. Billroth says: "That deleterious infectious matters may also enter the body otherwise than through wounds, especially through the lungs, cannot be doubted; we explain to ourselves thereby, in fact, the origin of all infectious diseases, that substances find their way into the organism which act as organic poisons upon the blood and upon the whole organism; but whether these disease-elements, which cause the infectious diseases occurring chiefly in the wounded, enter the organism otherwise than through the wound is a question the answer to which must depend very much upon the

particular interpretation of the cases observed."[1] That septicæmia may arise from an ulcer, covered by necrotic tissue, in the alimentary canal, or from a similar condition in the respiratory tract, is undoubted. The fact that many questions pertaining equally to the etiology of septicæmia have already been discussed under the etiology of pyæmia, has caused their omission here.

SYMPTOMS. 1. *Pyæmia.*—The symptoms to which pyæmia in its various forms gives rise are numerous and not easily described. Therefore it is necessary that the surgeon keep the fact constantly in mind, that the disease depends on *suppuration, cannot exist without it,* although it does not follow that in every case of suppuration there will be pyæmia; but it does follow that in every case of pyæmia there must be a vitiated condition of the blood, due to pus or its elements. Taking the natural order in which the symptoms occur, I shall begin with the chill which commonly announces the commencement of a new era in surgical cases, one of extreme danger to the patient, and the occasion of great anxiety on the part of the surgeon. The importance that will naturally be attached to this phenomenon must to a certain degree depend on the circumstances attending its occurrence, and therefore the following question will present itself: Is the chill associated with suppuration? A negative answer to this question, based on the fact that insufficient time has elapsed since the occurrence of the injury to render suppuration possible, can never fail to be a source of satisfaction to the surgeon whose experience has taught him to dread pyæmia.

Prof. Billroth has observed in 83 cases of true multiple pyæmia that 62 commenced with a chill, and 21 without; in 81 cases of septicæmia and simple pyæmia 24 commenced with a chill and 57 without. The number of chills in each individual patient occurred according to the following table:—

Number of patients,	19,	21,	14,	15,	9,	5,	2,	3,	4,	1,	1,	1.
Number of chills,	1,	2,	3,	4,	5,	6,	7,	8,	9,	10,	13,	14.

In one patient during three weeks sixteen chills were ob-

[1] Billroth's Surgery, vol. i. p. 218. New Sydenham Society Translation, vol. lxxiii.

served, and sex appeared to have no influence on the number; but probably the longer the duration of the disease, the greater is the number of the chills. Still there are chronic cases with a single chill, and acute cases with many. It rarely occurs that a patient has more than one chill in twenty-four hours. Billroth noticed among his patients only 16 who each had two chills, and only 6 who had each three chills in one day. The experience that fewer chills occur during the evening and night than in the morning and afternoon has been confirmed by statistics. Among 287 chills, 220 occurred from 8 A. M. to 8 P. M., while during the night, from 8 P. M. to 8 A. M., only 67 were observed. By this striking division of the twenty-four hours, Billroth desired to take into consideration the daily exacerbation, the usual daily irritation of the wound, the bandaging, and other manipulations. He saw, for example, a chill occur three times from the introduction of a sound, and twenty times after opening an abscess. The time which elapsed from first injury to first chill is seen by the following table:—

First chill began, times,	14,	19,	15,	9,	4,	3,	2,	4.
In the week,	1,	2,	3,	4,	5,	6,	7,	8.

Patients who had fever before the operation were more inclined to early chills than freshly injured healthy individuals. Billroth's experience was to have only the first chill before the end of the first week. It may be further stated that nervous, irritable patients suffer much more frequently from chills than those of a phlegmatic temperament. This fact has given rise to the opinion that the absorption of pus acts especially on the central nervous system. The chills in pyæmia are supposed by Billroth to be associated with inflammation, and he says: "It must be mentioned, as a matter of observation, that chills occur almost exclusively in the commencement of acute inflammations, and are intermittent only in intermittent fever and reabsorption of pus, while they do not occur in acute septicæmia."[1] But the fever in pyæmia rarely intermits; it is generally lower, however, in the morning than in the afternoon.

[1] Surgical Pathology, p. 344.

This symptom is even more important than the rigors in enabling the surgeon to make a correct diagnosis. The use of the thermometer enables us to determine at will the presence or absence of fever, and there is no disease in which it should be more frequently used than in the one now under consideration. Let it, however, be remembered that the temperature frequently becomes very high within a few hours after the receipt of an injury, or the performance of a surgical operation; that this high temperature is due to septic absorption and the diseased condition we designate septicæmia. Another condition, less marked, with an elevated but somewhat lower temperature, is usually spoken of as traumatic fever. In both the conditions, already mentioned, the fever may gradually increase for a few days, or possibly only hours, and then slowly disappear. The patient on or before the tenth day, in favorable cases, will be found to be free from fever. It will now be observed that sufficient time has elapsed for the formation of pus, and that the patient may, with or without a chill, be again attacked with fever. This fever, if moderate, may be designated as secondary fever, and, if more marked in its character, as pyæmia.

Again, in cases of severe acute septicæmia, the patient may die before the lapse of sufficient time for the formation of pus, or, as occasionally happens, before the disappearance of fever. Associated with the septicæmia, the system becomes contaminated still further by the absorption of pus, thus producing a condition appropriately called septo-pyæmia. One important peculiarity of the temperature in pyæmia is the sudden and great changes; thus, at one hour the temperature may be but slightly raised above the normal, and at the next the thermometer may mark 105° Fahr. These sudden changes of temperature in this disease are of frequent occurrence, and are not observed in other diseases, and therefore supply a very important diagnostic indication. It is impossible to know or even to anticipate with any degree of certainty, when the highest temperature will exist; consequently, Prof. Billroth and other writers have suggested the desirability of having a thermometer constantly kept in a position to indicate every change in the

heat of the body, and a careful attendant to note the same; but, thus far, I am not aware that it has been attempted, probably on account of the inconvenience it would entail on the patient, and the additional labor in nursing. It has been further observed that, during the existence of a chill, the temperature continues to steadily increase, and the highest seen during the whole course of the disease is attained during the hot stage which immediately follows the rigors. "This condition is followed by profuse cold perspirations. The perspirations which accompany this disease are most profuse, like those of advanced phthisis. They never precede the rigors, but may occur independently of them. They either are continuous in their duration, or exhibit more or less distinct exacerbations. They are occasionally accompanied by sudamina, and they do not abate with the use of any known remedy. . . . Occasionally perspiration is scanty; but, before death, a cold, clammy sweat and a 'tawny' discoloration of the skin occur."[1]

Besides the sudamina, there are frequently observed on the skin, vesicles, pustules, and boils, purpuric patches, and various discolorations. There is frequently observed to arise in the neighborhood of the wounds a reddish, erythematous blush, which soon extends to the whole limb, and commonly begins to disappear in the early part of the second week. This recently occurred in a patient under my care, and was speedily followed by an abscess of the knee-joint. The wound was situated at the hip-joint; at this point—on the lips of the wound—the first change in the color of the integument took place. It extended rapidly downward until it covered the foot, and even the toes; but the extension upward was slight, not much above the nates, on which there was situated at the time a bed-sore. It observed the same order in passing off as in coming on, viz., where it first made its appearance it first disappeared. The superficial veins leading from the wound were inflamed and cord like. This condition of the integument and the abscess of the knee-joint were followed by diarrhœa, on which medicines had no

[1] Braidwood on Pyæmia, p. 112.

beneficial effect. Diarrhœa continued, with occasional vomiting, until the death of the patient. The pulse in pyæmia is variable, often nearing normal as regards frequency, and at other times very frequent. It has been remarked in some cases, that the pulse seldom rose above 90 per minute, until near the fatal end. The pulse, although only moderately accelerated at the commencement of the disease, always becomes more rapid, frequent, feeble, and irregular toward the termination of the unfavorable cases; while in cases of recovery it returns gradually to the normal standard. In all cases in which the blood has been examined during the progress of pyæmia, the examiners have agreed in regard to the extreme coagulability, diminution of the number of red corpuscles, and the increase of granular spherical bodies. The red corpuscles, even in the earlier stages of disease, show evident indication of disintegrating; but, as the disease progresses, the microscopical examination steadily confirms, with increasing proofs from day to day, that the first idea was correct. There is a steady diminution in the number of red corpuscles, a steady increase in the number of pus- or possibly white blood-corpuscles. Epistaxis occasionally occurs, and also venous oozing from the wound. The condition of the tongue in pyæmia may be regarded as an important symptom, indicating the state of the alimentary canal; not, however, during the prodromal stage, but after the disease has progressed a few days. It is then observed that the tongue has become peculiar, smooth, dry, and frequently excessively red. This smoothness is caused by the collapse of the papillæ, and the dryness by a diminished secretion.

The organ now frequently appears as though covered with a thin layer of collodion, which had been caused to dry on the surface, presenting something of a glazed look. Again the tongue may be covered with brown crusts, and the teeth with sordes. These brown crusts and sordes are usually seen in advanced cases, following the first condition described. Much importance is attached to these brown crusts by many experienced surgeons, and although there may be very marked improvement in all other symptoms, still they insist on a very

guarded prognosis until the tongue has assumed a healthy appearance. Aphthæ on various parts of the mouth and pharynx are frequently present in chronic cases and absent in acute cases. Herpes of the lips sometimes occurs in the commencement of the disease; vomiting is comparatively rare; but there is, even in the early stages, a complete failure of the appetite with great thirst. Singultus is rarely present, possibly never in genuine pyæmia, but frequently in septicæmia, and occasionally in septo-pyæmia.

Diarrhœa is not so frequent or the stools so copious in pyæmia as in septicæmia. Billroth observed in one hundred and eighty cases of pyæmia, thirty-two cases of diarrhœa. It is impossible to determine whether those in which the diarrhœa occurred were pure or mixed pyæmia. The stools are generally of a pappy consistence, and often passed involuntarily in bed. There are, however, severe cases of pyæmia with a high fever, accompanied by obstinate constipation, which requires the administration of cathartics. Examination of the heart may, in rare, exceptional cases, show the existence of pericarditis, although usually the only indications of disease are the too feeble sounds. Auscultation and percussion over the lungs, even in cases of diffuse metastatic abscesses, are frequently unsatisfactory, for the same reasons as in miliary tuberculosis. The large deposits in the lungs are by these means readily determined. There may be a sensation of suffocation, the pneumonic sputa, the friction sounds of pleurisy, or pleuritic effusion; and the existence of these symptoms would materially aid in the diagnosis of metastatic abscesses. Enlargement of liver and spleen may be determined before death, and in connection with other symptoms would aid in diagnosing deposits in these organs. The urine in the first stage of the disease is scanty, high-colored, contains a large amount of salts, and is of a high specific gravity. Epithelial, fibrinous, and blood casts, and albumen, are also occasionally found in it during the course of the disease.

Billroth mentions a case in which there was complete suppression with uræmia. In many cases of pyæmia, suppuration of

the joints, one after another, takes place with great rapidity and with comparatively little pain; but occasionally some swelling, redness, etc., are present. In most cases these suppurations are easily diagnosed. Instead of the suppuration taking place in the joints, there are cases in which it occurs in the cellular tissue; and I have recently seen a case where abscess after abscess formed with such rapidity that within a single week the patient was literally covered with abscesses, from the crown of his head to the soles of his feet. Delirium generally exists during some stage of the disease, more frequently the last; it is then mild in its character, although active delirium has been observed in the first stage. Patients are low-spirited and very apprehensive of death. The face at the beginning of the attack may be flushed or pallid, and toward the end become careworn. The breath sometimes has a "sweetish" or "purulent" odor. The patient rapidly emaciates. The changes in the wound are in some cases very marked, even in the first stage of the disease. The suppuration which has been previously free and healthy, may suddenly be checked, the wound becoming dry. The discharge, if it continues, becomes scanty, thin, ichorous, or greenish. The granulations, if previously healthy, soon slough.

These changes do not always appear in the first stage, but, should they not then take place, they may be expected later in the disease.

Summary of the Symptoms.—Suppose that a patient, suffering with a compound fracture of the leg, has been admitted to a ward in a hospital in which the disease is prevailing. The surgeon is determined to save the limb if possible. The dressings are carefully applied, the wound cleansed, and the patient appears to be doing well until the twelfth day, when he is suddenly seized with a chill, which is followed by a high fever and profuse sweating. The countenance shows anxiety; the patient is evidently depressed; the face flushed; the conjunctiva congested; the pulse frequent; he complains of great thirst, and his breath has a sweetish odor. Several days have elapsed, the temperature of the body has been taken very frequently,

and always found above the normal. There is now observed a dusky and icteric discoloration of the skin; tongue peculiarly smooth, red, and glossy; disinclination to take food; frequently bronchial, pleuritic, or pneumonic symptoms now make their appearance, or the patient may complain of pain in some joint, which an examination will show to be slightly tender to the touch, œdematous, and the integument over it slightly reddened; abscesses form quickly. The wound assumes an unhealthy appearance. The discharge from it either ceases or is changed in character. Granulations slough, and abscesses now form in the cellular tissue with great rapidity. Diarrhœa may make its appearance; if so, the stools are passed involuntarily. The patient loses strength, and rapidly emaciates. At this stage of the disease he remains in an unconscious condition, and death soon closes the scene.

2. *Septicæmia.*—The symptoms of septicæmia may be sketched as follows: A patient is admitted to the hospital with a severe injury of the leg, requiring an amputation of the thigh. The amputation is performed, and the flaps are closed. The surgeon visits the patient twenty-four hours after the operation, and finds the pulse frequent; tongue, lips, and throat dry; skin hot, and the temperature of the body high. The patient replies accurately to questions, but with some hesitation. He is much inclined to sleep; has entirely failed to take nourishment; drinks frequently when aroused from his lethargic condition; and has vomited everything taken into his stomach since the operation. The dressings are now removed from the stump, when the foul odor of putrefaction greets the attendants. It is observed that there is considerable discoloration of the flaps, the edges of which are blackened. Above these blackened edges the integument is reddened, and slightly œdematous. The sutures are cut, and there escapes a few drachms, possibly ounces, of highly offensive, odorous fluid—the decomposed remains of blood, etc. Further examination of the flaps on their inner surface shows that their capillary circulation has ceased. The tissues, instead of presenting a life-like appearance, are now of a very dark-brown color, and occasionally mottled with dull

grayish spots, although the movements of the ligature at the point where it embraces the femoral artery show that the blood still rushes against the artificial boundary. Let us now leave our patient, without further comment, for the next forty-eight hours, when we will resume the examination. We now find the same dryness of the mouth that was previously noticed; the pulse is more frequent, and has become very feeble; he complains of much thirst; has vomited frequently; taken but very little nourishment, and that only at the urgent solicitation of the attendants. The temperature of the body is higher than at the former examination; has been steadily increasing; in the morning it is lower, however, than in the evening of the same day. The patient is lethargic; is suffering with a profuse diarrhœa. The odor of the stools is highly offensive; they are properly described as rice-water evacuations. Abdomen tympanitic; body bathed in perspiration; respiration rapid; slight bronchial symptoms; urine scanty, high colored, and contains albumen. The examination of the stump shows that gangrene has extended rapidly, involving not only the flaps, but a portion of the adjacent tissues. The stench arising from the wound is almost stifling. The decomposing fluids are continuously dropping. That portion of the thigh not already gangrenous is now very œdematous; the integument covering it is much discolored, being of a dark, icteric, or reddened hue. We now allow twenty-four hours to elapse, and then make our final examination. The patient's tongue is more moist, body still bathed in perspiration; eyes dull; conjunctiva icteric, and the same hue extends to the body, though in a less marked degree; pulse very frequent, feeble, and not easily counted; temperature below normal. Singultus is now present, and has been during the last twenty-four hours very troublesome. Bronchial symptoms, combined with marked symptoms of œdema of the right lung; diarrhœa the same; gangrene still extending.

It must be admitted that the report here offered shows only the symptoms that are found in a single class of cases. These symptoms vary much in different cases, and the variations are especially marked in the acute sepsis mentioned by Maisonneuve

under the head of "Gangrene Foudroyante." In these cases there appears, immediately after the receipt of an injury, enormous œdema about the wound, which extends rapidly in every possible direction, followed by the death of the patient within a few hours, unless prompt measures are adopted. The puncture of the cellular tissue or the bloodvessels involved in the œdema prior to the death of the patient, gives rise to the escape of a highly offensive gas. Roser mentions a case of this disease in which he promptly amputated the limb of the patient through the healthy parts, without even waiting for the administration of an anæsthetic, and the patient recovered. The symptoms of septicæmia must, necessarily, greatly depend on the condition of the patient and the amount of septic material introduced. The intelligent surgeon has little difficulty in making the differential diagnosis in pyæmia, septicæmia, and septo-pyæmia. The chill at the commencement of pyæmia may possibly be mistaken for the chill of intermittent fever; but the proper use of the thermometer cannot fail to correct this error. It will be remembered that in cases of intermittent fever there is, usually, a distinct intermission; but in pyæmia the fever is constant, with a tendency to exacerbations. Again, the chills of intermittent fever occur usually at regular intervals, while in pyæmia they are irregular.

Differential Diagnosis.

THE GENERAL ORDER OF THE OCCURRENCE OF SYMPTOMS.

Pyæmia.	Septicæmia.
1. Chill (rigor).	1. Absence of chill the rule.
2. Fever rarely intermits entirely.	2. Fever steadily increases, but lower in the morning.
3. Sudden and great changes in temperature; followed by profuse cold perspirations.	3. Temperature high at beginning, increases, and toward end becomes subnormal. Surface moist, but without profuse sweatings.
4. Pulse variable; toward the end rapid, feeble, and irregular.	4. Pulse rapid, increasing toward the end.
5. Facies at beginning flushed or pallid; toward the end careworn.	5. Facies expressive of a dull, listless condition.

PYÆMIA.	SEPTICÆMIA.
6. Tongue smooth, dry, and excessively red; later, brown, and covered with sordes.	6. Tongue, lips, and throat dry at beginning, toward the end moist. Thirst is marked.
7. Diarrhœa of a pappy consistence.	7. Rice-water evacuations, very offensive. Vomits everything that is taken.
8. Urine, sp. gr. high, albumen and casts.	8. Urine, sp. gr. high, albumen and casts.
9. Epistaxis.	9. Lethargic condition from the beginning; increasing to the end.
10. Mild delirium toward the end.	10. Icteric hue of eyes and conjunctivæ.
11. Aphthæ in mouth and throat; sudamina (vesicles and pustules), and purpuric patches.	11. Singultus.

Signs.

1. A reddish erythematous blush in the neighborhood of the wound, which soon extends over the whole body.	1. Integument red and slightly œdematous about the wound.
2. Suppuration checked, wound becoming dry; if the discharge continues, it becomes scanty, thin, ichorous, and greenish.	2. A large quantity of fluid escapes from the wound, marked by its putrefactive odor.
3. The granulations, previously healthy, soon slough, followed by venous oozing.	3. The tissues about the wound are brown and mottled with grayish spots, and if a large arterial trunk has been ligated, the blood distends its lumen up to the point of ligation.

Pathognomonic Signs.

1. Existence of suppuration.	1. Insufficient time from receipt of injury for suppuration to take place.
2. Extreme coagulability of the blood.	2. Diminished coagulability of the blood.
3. Increase in number of granular spherical bodies in the blood.	3. The number of granular spherical bodies in the blood not increased.

Complications.

1. Suppuration of the joints following one another with great rapidity.	1. Œdema of the lungs.
2. Suppuration in cellular tissue.	
3. Pulmonary abscesses.	
4. Abscesses of liver and spleen.	
5. Feeble heart sounds.	
6. Pericarditis.	

PATHOLOGY.

Pyæmia. Simplex.	Pyæmia. Multiplex.	Septicæmia.	Septo-pyæmia.
1. Destroys life by the height and duration of the fever.	Destroys life by the vitiated condition of the blood.	Destroys life by a putrid poison in the blood.	Destroys life by a vitiated condition of, and the presence of a putrid poison in the blood.
2. Extensive suppuration, generally without contact of air. Absence of metastatic deposits.	Numerous metastatic abscesses, containing thin, fetid pus, especially in the lungs and liver. Serous cavities contain sero-pus.	Absence of purulent or ichorous deposits.	The appearances are those of septicæmia, complicated in greater or less proportion, with those of pyæmia.
3. Slight increase in the coagulability of the blood, and in the number of granular spherical bodies which it contains.	Marked increase in the coagulability of the blood and in the number of granular spherical bodies which it contains.	Diminished coagulability of the blood.	The appearance of the blood not characteristic of either pyæmia or septicæmia.
4. *Post-mortem* lesions, sometimes nearly or quite negative.	*Post-mortem* lesions, generally positive and characteristic.	*Post-mortem* lesions, sometimes, nearly or quite negative.	*Post-mortem* lesions, may be negative or mixed.

CAUSES.

Pyæmia.	Septicæmia.
1. Contamination of the blood by pus or one of its constituents. The pus may be ichorous, putrid, fluid, or dried. Pus taken from a cold abscess has very little effect.	1. The reception into the blood, through a wound of the lungs, of a putrid poison, other than pus or one of its constituents (the intensity of action depends principally on the quantity of poison introduced into the circulation).
2. Sources of contamination of the blood which may cause pyæmia.	2. Circumstances which are favorable to the development of septicæmia.
a. By means of the wound through the bloodvessels.	*a.* The retention of the fluids within the flaps after an amputation; the warmth of the parts and the presence of the atmosphere affording favorable conditions for rapid decomposition.
b. Laceration of the tissues by fragments of bone.	*b.* Recent wounds and lowered vitality, due to loss of blood or shock.
c. Suppurative periostitis.	*c.* Opening of medullary cavities.
d. Inflammation of exposed medulla.	*d.* Abraded, granulating surfaces.
e. Sloughing of the soft parts.	*e.* An abrasion in the respiratory or alimentary tract.
f. Favorable conditions for the change of laudable to putrid pus.	

Pyæmia.	Septicæmia.
g. Vitiated condition of the atmosphere; the poisonous substances passing into the blood through the lungs, or an abrasion of the skin.	
h. Spontaneity of origin. (?)	
i. Effect of certain seasons and certain locations.	
j. Contagion.	

Treatment. 1. *Pyæmia.*—The treatment of pyæmia and septicæmia necessarily opens the whole question of surgery as it pertains to the management of wounds. The prevention of these diseases is of primary importance, and he who desires to save the greatest number of lives possible is, therefore, compelled to use all available means for the accomplishment of this object. The knowledge that the profession now possesses in regard to variola and its management teaches us an important lesson. The prevention of both pyæmia and septicæmia is probably within the scope of possibility in the large majority of cases, but the cure of the affection, when fully developed, is always doubtful and frequently impossible. Every surgeon will readily admit that, were it possible to secure union by first intention in all cases of wounds, then it would be impossible for either pyæmia or septicæmia to occur in surgical practice. Therefore, it follows that the character of the wound, the method of operation, the surroundings of the patient, and the character of the treatment thus become proper points to consider in this division of the subject. The character of the wound and its relations to pyæmia and septicæmia have already been briefly referred to under the etiology of these diseases. The various methods of operating, their respective advantages and disadvantages, require more consideration than space will admit of here. The surroundings of the patient is a subject of vast importance in a prophylactic view, and should never be lost sight of in the construction of hospitals. I desire here to express my firm conviction that surgical pyæmia is *essentially* and almost *wholly* a hospital-disease. It is true that there are some eminent surgical authorities who deny its contagiousness, but this denial

seems to me a mere quibble opposed to the etiology and history of the disease. The question of surroundings for the patient presents, to my mind, the following demands as *sine quibus non* for obtaining the best results in surgery: (1) Absolute purity of the atmosphere. (2) Absolute cleanliness. This demand should be strictly enforced in regard to the wound, the patient's body, the bedding, and everything else, including nurses and instruments. (3) Moderate and equable temperature, containing a proper amount of moisture. (4) Proper quantity of nutritious and easily-digestible food, with suitable drinks, etc. (5) Cheerful and pleasant surroundings, especially in companions, nurses, and other attendants. It may be objected to these conditions that they can never be obtained; I must confess that perfection in every detail cannot always be obtained, but I am thoroughly convinced that he who makes a determined effort in this direction, will succeed far better than that person who is constantly looking about for some excuse for his negligence. The overcrowding of surgical wards with severe surgical cases, especially where the ventilation is defective, is only one step removed from homicide. I remember a small ward, crowded with the worst surgical cases which could be conveniently collected, in which there was less than six hundred cubic feet of air to each patient, and this in mid-winter, with no other means of ventilation than that furnished by lowering or raising the windows; the odor of pus constantly pervaded this ward in spite of fruitless attempts made every day to purify it; the windows were frequently lowered by the attendants, but very quickly closed by some of the patients. The result was here, as had been anticipated, an outbreak of pyæmia, whlch carried off three of the nine patients. There should be allowed each surgical patient, while there is considerable suppuration still going on, two thousand cubic feet of air, and more if possible. The ventilation should be so arranged that neither the patient nor the nurse can change it. The ventilation ought to be wholly under the control of the attending surgeon. There are very few surgeons who give to these important matters the time and consideration that they should receive, and few who accomplish here as much as they

might. The question of treatment brings up the entire subject of antiseptics. The favorite remedies of this class are carbolic and salycilic acids, bichloride of mercury, permanganate of potash, chloride of zinc, and liquor sodæ chlorinatæ. There is no doubt that good results may be obtained with any of these remedies. Much more will depend on the manner in which they are used than on the remedy itself. The surgeon should never forget that he uses medicines merely as agents to enable him to accomplish certain objects, and, keeping these in mind, he need very seldom fail with his antiseptic when the object is to prevent putrefaction in an open wound. He should at all times, by the proper use of the senses of sight and smell, be able to decide promptly whether or not the antiseptic is accomplishing the work. In certain cases, while using certain antiseptics, it will be found advantageous to keep up constant irrigation, and in other cases, by certain methods of treatment, the antiseptic is stored up for gradual use, as may be required.

Therefore, it appears certain that each method of treatment may possess special advantages in particular cases, and probably the same may be said ot the antiseptic itself. The importance of this subject may be more fully appreciated when it is remembered that it is admitted by the best surgical authorities that more lives are lost from septic infection than from all other causes combined during a war. The further consideration of this subject may be arranged for convenience under the heads of local and general treatment. The local treatment of the wound should, if possible, be of such a character as to prevent the absorption of either putrid substance or pus. It, therefore, becomes highly important in cases of amputation and other operations, that all tissues injured to such a degree as to be likely to excite either putrefaction, irritation, or inflammation, should be removed. The same care is necessary in removing all foreign bodies from the wounds in cases where no operation is performed. The amputation of the injured limb may be necessary to prevent the development of these diseases, or may be resorted to in certain rare cases after the origin of pyæmic symptoms; however, in the latter instance great care should be

taken to remove all the tissues already infiltrated with serum, otherwise nothing will be gained. The use of the surgeon's knife at the proper time may be the best prophylactic measure against both pyæmia and septicæmia, but this measure should be directed by an intelligent mind, and the instrument guided by a practised hand. Again, it is found that opening a large medullary cavity is attended with danger to the patient. This fact teaches an obvious lesson. The wound existing, or the operation having been performed, the surgeon now turns his attention to the prevention of putrefaction and inflammation. The first source of danger, requiring attention from the surgeon, is the fluid escaping from the wounded surface. Do not allow it to undergo putrefaction in contact with the wound. Whether or not there is danger to be apprehended from inflammation, depends largely on the character of the wound; contuso-lacerated wounds are especially liable to become inflamed, and many other varieties, only in a less degree. The use of sutures is a question to be decided in each particular case. The same may be said of the use of antiphlogistic remedies. The question having been decided in favor of their use, then comes the selection of the special remedy. Prof. Billroth has recently given this subject much thought, and thus records his opinion; he inclines to the belief that the bath may be properly used in the treatment of contuso-lacerated wounds confined strictly to the hands and feet. Here the patient finds comfort when the temperature of the bath is properly regulated and the limb allowed to float in the water. In the majority of cases he prefers the use of ice either with or without the ice-bags. He found that the application of ice to a limb lowered the general temperature of the body, diminished the size of the capillaries in the diseased parts, and retarded putrefaction, also lessening the absorption of putrid substances, and limiting the extension of inflammation. He also claims that wounds heal kindly even during the continuation of the treatment. There are cases in which the use of leeches may be advantageously resorted to for the purpose of relieving inflammation. Warm poultices may be used for the purpose of effecting a more speedy removal of

the necrotic tissues covering the surface of the wound than would otherwise take place, but it should never be forgotten that the "poultice is a means of applying continuous heat with moisture, and of softening the tissues. An afflux of blood takes place to the parts, the vessels dilate, the tissues, softened by the combined influence of heat and moisture, permit the easy diffusion of fluids. . . . Foul-smelling wounds, requiring the use of poultices, are best treated with the yeast or charcoal poultice. . . . The application of poultices sometimes degenerates into abuse. If too long continued the skin becomes white, wrinkled, and sodden; small abscesses or boils form, and the vessels of the part very slowly regain their tone. If kept too long in contact with wounds or ulcerated surfaces, the granulations become pale and flabby, and the healing process is retarded. Applied indiscreetly to inflamed joints, they may promote suppuration, and thus permanently injure these structures. If kept long in contact with a large extent of surface, they will lower the general tone and vigor of the system, depress the systemic circulation, exhaust the irritability of the vaso-motor nerve, and thus seriously embarrass the reparative process, if not wholly prevent repair."[1]

It appears probable that more injury than good results from the use of poultices in cases where there is reason to fear pyæmia. I think, in all such cases, the use of the poultice should be limited to the cleansing of the wound by hastening the removal of necrotic tissues, and am satisfied that the practice of wrapping the whole arm or leg in hot poultices, in cases of cellulitis arising in connection with septic absorption, is highly *injurious, especially when continued for a long time.* Free scarification of the integument where there is great tension of the parts may possibly become necessary for the purpose of relieving pain and aiding the circulation; but the surgeon should not forget here that he is opening new avenues for the admission of the poison. Abscesses should be opened as soon as discovered, in the majority of cases, because of the pain and fever caused by them. Tincture of iodine is serviceable, in certain stages of

[1] Bartholow, Materia Medica and Theurapeutics, pp. 541, 542.

inflammation, as a local application. Caustics may be used to aid nature in throwing off a slough, and occasionally as a stimulant to an indolent wound which fails to granulate properly. Healthy granulations should never be destroyed lest their destruction should open other channels for the admission of the septic poison into the system. Drainage-tubes may be required to prevent any accumulation of pus within the wound. It has been suggested as a prophylactic measure against pyæmia that a ligature of the veins between the thrombus and the heart would be a rational measure. It seems to present an almost insurmountable obstacle in the determination of the venous branch which should be ligated, and the impracticability of ligating the principal venous trunk of the limb. However, it is said that Lee has successfully ligated the cephalic vein at the elbow, in two cases of injury of the hand, after the appearance of the pyæmic chill. It has also been suggested that transfusion of healthy blood ought to be tried in suitable cases of this affection. In the general treatment of pyæmia there have been recommended at various times a great variety of drugs; but the general want of success attending their use leaves comparatively few to be mentioned here. The mineral acids are still employed, and are found, at least, agreeable drinks, and as such can still be recommended. The sulphites of magnesium, sodium, potassium, and calcium are employed by Giovanni Polli for the treatment of typhus fever, scarlet fever, smallpox, septicæmia, and pyæmia. He further suggests that the medicine should be given until the whole quantity taken bears to the weight of the patient's body the proportion of one to a thousand. The experiments made on animals with these salts seem to confirm their value in the treatment of septic disease. It is certainly true that animals treated with these salts are not so easily affected by septic poison as those which have not received the treatment. Further, it has been shown that putrid substances when mixed with either the permanganate of potassium or the carbolate of sodium, and then injected, are harmless, although the same quantity of putrid matter without the salts destroys life. Quinine certainly, in most cases of pyæmia, is a valuable agent. In large doses it

enables the surgeon to reduce the temperature of the patient, and in smaller doses it frequently serves a valuable purpose as a tonic. It has also undoubtedly considerable value as an antiseptic. Labbin has recommended the use of large doses of ergotine in infectious fevers, which should begin on the day the injury is received. The use of drastic cathartics should be avoided, and also sudorifics, on account of their prostrating effects. In some cases hypnotics may be required to secure sleep. Tonics are always more or less useful. The free use of stimulants is also indicated. Brandy, wine, and whiskey may be used by the patient in accordance with his own taste. Musk, ammonia, and camphor are occasionally required. However, it should not be forgotten that, in cases where the disease has become fully developed, the usual termination is death, few recoveries being recorded. In the early stages of this affection, by the removal of the patient from an overcrowded hospital ward to some place where pure air, proper hygienic arrangements, and a judicious use of medicines can be obtained, recovery may take place; but under other circumstances the prognosis is exceedingly grave.

2. *Septicæmia.*—The treatment of septicæmia in most particulars is the same as that of pyæmia. The first effort should be to prevent the development of the disease, and the second, to cure the patient in cases where the disease has already developed. It is not in our power to limit or in any way regulate the primary injury, but we are obliged to take the patient as he is. The amount of destruction to living tissues may be great or small. The question of an operation, the character of the same, and the subsequent management, must be determined in accordance with the circumstances of each particular case. The primary death of the parts is generally due chiefly to the injury itself; the secondary frequently to bad surgical management. Let us take a case in which the primary injury has been severe, greatly diminishing but not destroying the circulation in the injured parts; here the immediate application of ice would be locally injurious, but an evaporating lotion or warm applications might assist nature. We have already seen, while speak-

ing of the treatment of pyæmia, that the continuance, for a long time, of hot applications, is frequently injurious, or *even pernicious*. Let us now call to mind a case of contusion situated in the neighborhood of a large joint, where the injury to the soft parts will probably be followed by much sloughing if ice is used ; but the great danger is inflammation of the synovial membrane, and to avoid this danger, the surgeon requires perfect rest of the parts, the application of leeches, and finally cold, or even ice. It is humiliating to the profession that we are obliged, even at this date, to admit that the treatment of septicæmia is largely symptomatic. The profuse choleraic diarrhœa which generally accompanies this disease may be regarded as an effort of nature to eliminate the septic poison ; but, nevertheless, it is so prostrating in its effects on the patient, that it requires to be controlled with properly selected astringents, and these remedies may be still further aided by the use of tonics and stimulants.

The treatment of septicæmia may be summarized as follows: 1. A strict adherence to the five rules given under the head of prophylactic treatment. 2. The avoidance of all putrefaction in contact with the wound, especially prior to the development of sufficient granulations to completely cover its surface. This object is to be accomplished by the removal of all necrotic tissues, the avoidance of putrescent fluids by cleanliness and the proper use of antiseptic agents. 3. Free use of the alkaline sulphites and hyposulphites. These drugs should be used, in all cases where there is reason to anticipate the development of septic disease, as soon after the receipt of the injury as praticable, but should not be neglected even after the development has occurred. 4. Sulphate of quinine should be used in all cases where the temperature is above 100 degrees Fahr. and its persistent use in large doses may be necessary to prevent its rising still higher. It will be remembered in this connection that experience has taught that "a temperature of 108.5° Fahr. is the limit beyond which life can no longer exist," and a much lower temperature is not without danger. The essential danger of fever in acute diseases consists then in *the deleterious influence of a high temperature on the tissues.*

CHAPTER XI.

A CONSIDERATION OF ERYSIPELAS, GANGRENE, OSTEO-MYELITIS, TETANUS, ETC., AS WOUND COMPLICATIONS WITH SPECIAL REFERENCE TO THEIR ETIOLOGY, PATHOLGY, SEMIOLOGY, AND TREATMENT.

ERYSIPELAS.—This term is derived from two Greek words ἐρύω I draw, and πέλας near; and is applied to this disease because of its well-known tendency to spread. The cutaneous form of this disease is further characterized by a circumscribed redness of the skin, and by a febrile state. Redness of the skin belongs to other cutaneous diseases, viz., scarlatina and measles; but in these cases it is not circumscribed. Erysipelas also differs from these diseases by the absence of any inflammatory complication of the mucous membrane of the respiratory tract—such as the angina of scarlatina—or the bronchitis of measles. The redness of erysipelas also resembles that of erythema, but the latter disease is not accompanied by fever. There is no reason to doubt that erysipelas was known in prehistoric times, since its origin is so intimately connected with wounds, and it is likewise mentioned by nearly all of the ancient medical authors. Hippocrates mentions cases of erysipelas which arose from scalp wounds in which the bones of the cranium had been exposed; and also epidemics of this disease. In describing the symptoms of this disease when it prevailed as epidemic, he says: "In many cases erysipelas from some obvious cause, such as an accident, and sometimes from even a very small wound, broke out all over the body, especially in persons about sixty years of age, about the head, if such an accident was neglected in the slightest degree; and this happened in some who were under treatment; great inflammation took place, and the erysipelas

quickly spread all over. In the most of them the abscesses ended in suppurations, and there were great fallings off [sloughing] of the flesh, tendons, and bones; and the defluxion which seated in the part was not like pus, but a sort of putrefaction, and the running was large and of various characters."[1] This able translator comments, in a foot-note, upon the above as follows: "The history of the epidemical erysipelas here described cannot fail to prove interesting to the modern reader. I need scarcely remark that epidemics of a similar nature are occasionally met with in Great Britain at the present day. I myself have encountered two such epidemics in the locality where I am now writing, the one in 1823, and the other in 1846. As described by Hippocrates, the disease sometimes supervened upon a slight injury, and generally terminated in gangrene." Both idiopathic and traumatic erysipelas are mentioned in the writing of Celsus. Galen has also written extensively on erysipelas; but it is not essential for our purpose to trace the literature of this subject any further. We shall, therefore, *en passant*, merely remark that the disease which we are now considering is unquestionably inflammatory in character, but under the head of its etiology we shall give this subject a much more careful consideration. It should be further understood that we feel compelled in our classification of erysipelas to mention all the varieties; since it is claimed by many eminent authors that the disease can only originate in those cases in which there is an open wound. We are *not now prepared* to assert that this claim has been proven, but the facts and arguments adduced in its favor are certainly entitled to our careful consideration in another portion of this chapter. The adjectives applied to the term erysipelas are commonly employed to convey an idea of its origin, degree of severity, or the anatomical parts affected by the disease. We, therefore, apply the term *traumatic erysipelas* to those cases which have originated in some recognized solution of continuity of the soft parts, involving necessarily a

[1] Works of Hippocrates translated from the Greek by Francis Adams, LL.D., Surgeon, vol. i. p. 400.

part, or the whole thickness of the integument, while the term *idiopathic erysipelas* is applied to this disease, when it is supposed to originate independent of a wound, and it is consequently intended to designate a primary affection. The qualifying terms, *simple*, *phlegmonous*, *œdematous*, and *gangrenous* are employed to express certain symptomatic or pathological conditions, while the words *cutaneous*, *cellulo-cutaneous*, and *cullular* are expressive of the nature of the disease, since they convey to our minds an accurate idea of the tissues which are involved in the morbid process. The term *facial*, *scrotal*, or *pudendal erysipelas* is employed to designate the particular portion of the body which is diseased. *External erysipelas* is used in contradistinction to *internal erysipelas*, which is occasionally applied to those forms of diffuse inflammation which affect the mucous or serous surfaces, or the lining membrane of arteries, veins, and lymphatics.

Etiology.—It may not be amiss, since erysipelas is an inflammatory disease, to devote a brief space to the consideration of its origin. The surgical literature of the present day, we think, fully justifies the conclusion that some form of irritation is the sole cause of every inflammation. In cases of amputation wounds, the irritation may be caused by muscular contractions, especially in those cases where the flaps have been cut too short, or it may arise from the sutures employed; but, unquestionably, the micro-organisms are the most common cause of traumatic inflammation. The inflammation arising from the two causes first-mentioned may be conveniently designated as mechanical, and it rarely if ever gives rise to any severe constitutional symptoms; but the septic varieties of this disease, which are produced by micro-organisms within the wound, frequently cause severe constitutional disturbances, and occasionally even remote pathological lesions. A very important etiological question arising in connection with the different varieties of septic inflammation, such as erysipelas, osteo-myelitis, pyæmia, etc., is: Do each of these diseases take their origin from distinct and separate species of micro-organisms, or can the effect of these parasites be so changed by the soil in which they chance to fall, or other surrounding circumstances, as to pro-

duce morbid conditions in which the symptoms and pathological lesions differ so widely? Prof. H. Gradle has remarked that "The question is a difficult one to answer, since bacteria of widely differing powers may resemble each other in form. Hence, if a species cultivated in a flask be contaminated by other germs accidentally introduced, which is very likely to happen, the gravest errors may arise. But the more our methods gain in precision, and the more positive our experience becomes, the more do we drift toward the view that each variety of bacteria represents a species as distinct and characteristic as the separate species among the higher animals. From a medical stand-point this view, indeed, is the only acceptable one."[1] It should be observed that the opinion expressed in the above quotation is not only in perfect harmony with the laws governing reproduction in the animal creation, but it is also in perfect accord with those of the vegetable kingdom. It is, therefore, extremely probable that the *contagium vivum* of erysipelas produces only its kind; and that the same laws govern the reproduction of all contagious or infectious diseases. The study of the etiology of erysipelas necessarily involves all questions relating to the origin of the germ, and the conditions of propagation; and consequently the question may be properly asked here, whether traumatic and idiopathic erysipelas are the same or different diseases? In answer to this, it may be boldly asserted that in every instance the so-called idiopathic cutaneous erysipelas is certainly the exact counterpart of the cutaneous traumatic form of this disease, *i. e.*, barring the question of its origin. It may, therefore, be properly assumed that these morbid conditions *are not* distinct varieties of erysipelas, but essentially the same disease, having their origin in the same species of micro-organisms, which reproduce themselves in the same kind of fluid, subsist on the same sort of food, and finally affect the same tissues in the same manner. Prof. Billroth says: "I have had little experience of so-called spontaneous erysipelas of the head and face; but I believe that it is in the highest

[1] The Popular Science Monthly, vol. xxiii, p. 584.

degree probable that it almost always proceeds from some slight wound (a scratch on the scalp or face), or from some inflammatory accident (nasal catarrh or angina), and that it is due to a septic cause."[1]

We have already assumed that eysipelas has its origin in micro-organisms, and the following is now offered in support of this opinion: "In specimens of skin taken from thirteen cases of erysipelas, Fehleisen was able to demonstrate in each the same form of micrococcus arranged in rows. These were always to be found in the lymph vessels, sometimes also in the lymph cavities (lymphspalten) and juice canals (saftkanalchen) of the skin, but never in the bloodvessels. The observations of the author correspond entirely in this respect with those of Koch. The author's attempts to obtain cultivation of these organisms outside of the body by using the contents of freshly opened erysipelas vesicles were futile. Success was finally attained by taking freshly excised bits of erysipelatous skin, and placing them immediately in warmed infusion of meat and gelatin; then allowing this to stiffen, and preserving it at a temperature of 20° C. In two days were to be seen upon the cut surfaces of these bits of skin minute white points, which gradually increased in size. These, when inoculated upon other gelatine preparations, presented entirely characteristic development, forming white masses (Rasen), which lined the punctures of inoculation, and slowly developed, reaching maturity in about six days. The microscope showed them to be composed exclusively of the characteristic micrococcus of erysipelas, arranged in rows. It only remained to demonstrate the fact that these cultivated organisms were capable, when inoculated upon animals or man, of causing true erysipelas. Seven rabbits were inoculated with the same upon the tips of the ears. Of these seven rabbits six developed, with elevation of temperature, a well-marked, sharply bordered, and wandering redness, characteristic of erysipelas. In one case the affected ear was amputated, and the lymph-vessels of the same were found to be filled with the peculiar micro-

[1] Surgery, vol. ii. p. 14 *et seq.*, published by New Syd. Society, 1878.

coccus exactly as in erysipelas of the human subject. The author, furthermore, by inoculation of the same cultivated micrococcus upon human beings, in six instances succeeded in causing undoubted erysipelas, ushered in by a chill, accompanied by high fever, and spreading over a greater or less extent of the skin. He is of the opinion that the transmission of erysipelas from man to man belongs to the exceptions, and that, as a rule, the micrococcus peculiar to the disease being capable of existing and multiplying outside of the body, the wound infection which causes erysipelas is, so to speak, accidental. In this connection it is worthy of notice that attempts at cultivation of this organism, under ordinary temperatures, and upon the cut surface of potatoes, were successful. Exposure of these micrococci for forty-five seconds to the action of a three per cent. solution of carbolic acid, and for fifteen seconds to the action of a one-tenth of one per cent. solution of corrosive sublimate, rendered them sterile, and incapable of cultivation in gelatine."[1]

Thus far our attention has been directed to the exciting cause of erysipelas, and we have now presented in the above quotation many of the essential facts connected with the reproduction of these organisms, and their agency in the production of this disease as shown by experimental research. The opinion expressed in the above, that the micrococci of this disease *are capable of multiplying outside of the body may be fairly questioned;* although this view materially strengthens the position of those observers, who have persistently claimed that certain atmospheric conditions, unusual moisture, etc., are favorable to the development and spread of erysipelas. We are willing to admit that the erysipelatous germs retain their vitality in the air, and are disseminated throughout hospital wards and other rooms by the atmospheric currents; but we nevertheless incline to the opinion, that their multiplication is chiefly confined to those tissues in which the organisms have accidentally found lodgment, and that their presence and rapid increase are indicated by the characteristic symptoms of erysipelas. The red-

[1] The Boston Med. and Surg. Journal, vol. cvi. p. 418 *et seq.*

ness of the skin in cases of cutaneous erysipelas also indicates the extent to which the micrococci have penetrated the lymph-vessels and lymph-cavities. Dr. Campbell De Morgan has called attention to this peculiarity, which he says: "Is sometimes so great that the inflammation will spread over considerable parts of the body, while those previously affected have returned to their natural state (*E. ambulans*). In a case recorded by La Motte, the inflammation began in the head and extended down the neck and shoulders, and so continued spreading downward, the upper parts getting well, until no portion of the surface of the body had escaped, even down to the fingers and toes. . . . In other cases the inflammation will not spread continuously, but will invade distant parts, subsiding in one spot while it breaks out in another. To this form, which illustrates the alliance between erysipelas and the eruptive exanthemata, the term erratic (*E. erraticum*) has been applied."[1]

It is now thought that the peculiarities of this form of erysipelas may find a rational explanation in the supposition that the patient has accidentally distributed and inserted the micrococci by a very natural use of his fingers. In order to accomplish effectually this object, it is only necessary that the finger nails and tips, in the act of scratching the diseased parts, should take up some of these germs which are readily introduced into healthy integument by the same pleasure-giving practice. I am also convinced by observation, that many cases of so-called idiopathic erysipelas may be satisfactorily explained on a similar basis. The patient's fingers having been dipped in a wound secretion, may carry the germs to distant parts of the body when they are readily introduced into the integument by scratching. It is also quite certain that these germs frequently excite disease when introduced into a fresh scratch; although they apparently do little or no harm in the old wound from which they were taken. In this manner we may frequently explain the origin of facial erysipelas in cases of scalp wounds in which the disease

[1] A System of Surgery, Holmes, vol. i. p. 218 *et seq*. Published by W. Wood & Co., N. Y. 1869.

does not have its starting point from the edges of the traumatism. Thus far in our study of the etiology of erysipelas, we have considered only the *contagium vivum* or the exciting cause of this disease, but there are other agencies which prepare the soil for the seed, and are therefore worthy our attention.

Predisposing Causes.—The chief predisposing causes may be briefly mentioned as follows: A disregard of the necessary *hygienic conditions*, the existence of suppurating wounds or certain diseases, especially *diabetes* or any *morbid condition of the kidney attended with albuminuria*, and also a *hereditary predisposition.* A neglect of the necessary hygienic conditions is unquestionably the most prolific predisposing cause of erysipelas, and in fact the same remark is equally applicable to all cases of septic disease. The practice of antiseptic surgery and the more careful study of surgical hygiene during the last fifteen years have demonstrated to our satisfaction what may be expected when hygienic laws are thoroughly understood and strictly obeyed. During this eventful period, science has enabled her most earnest devotees to readily change the worst pest houses into salubrious hospitals. The evils arising from a disregard of the necessary hygienic conditions can only be fully appreciated when it is remembered that this department of medical science takes cognizance of everything which relates to the preservation of health. It therefore demands the exercise of wisdom and the practice of temperance in eating and drinking. The opulent are predisposed to erysipelas and many other diseases in consequence of their high living, want of exercise, and general indulgence in luxurious and enervating habits. The poor suffer from similar diseases because of their deprivation of the necessaries of life, together with the habitual intemperate use of stimulants and exposure to the various depressing conditions arising from bad food, overwork, etc. Another strongly predisposing cause of erysipelas is found in the impurities of the atmosphere, which endanger alike the lives of the rich and poor. The rich man's palace is commonly constructed with especial reference to luxurious ease, and with an entire disregard to the laws of health or the preservation of life. It is therefore

customary in these dwellings to sedulously exclude *all pure air*, to breathe over and over the foul gases emanating from water closets and the other so-called modern improvements, and likewise to exclude, as nearly as possible, the sunlight, lest it might fade the rich tapestry or drapery. There is likewise a hidden danger which frequently menaces the lives of the occupants of these fine dwellings, arising from the practice of entrusting the entire management of all household affairs to ignorant servants, who may have a sufficient regard for external cleanliness, but no proper appreciation of that neatness which is required in the care of the various house closets and the hidden nooks and corners, in order to preserve the premises free from contamination. The tenement houses and hovels occupied by the poor are even more faulty in their construction, and are often neglected and even filthy. It may therefore be justly asserted that the domiciles of both the rich and poor are so constructed as to meet the demands of our modern civilization, but at the same time endanger both life and health, since they deprive their occupants of two of God's *best blessings, sunlight and pure air*. It is, however, well known that the predisposing causes of septic disease are especially active in the majority of our hospitals. This opinion was confirmed by "the exhaustive investigation made in 1864, by Bristowe and Holmes into the sanitary conditions of the hospitals of the United Kingdom and of those of Paris, under the directions of the medical officer of the Privy Council, which led them to the conclusion that 'whenever surgical diseases presenting open sores (especially operation cases and cases of accident) are received, hospital diseases, such as erysipelas, pyæmia, and phagedæna, are likely to arise. The liability of these affections to originate and spread is considerably influenced by concentration of 'traumatic' atmosphere, but their development and spread are both chiefly dependent on want of cleanliness, bad drainage, overcrowding, defective ventilation, and the like.' They saw abundant reason to satisfy themselves that the health of hospitals is influenced in a far greater degree by conditions belonging to hospitals them-

selves, than by conditions of external atmosphere, of site, of soil, and the like, and that the healthiness of hospitals is less dependent on the form and size and distribution of wards than it is on the ventilation, drainage, cleanliness, and proportion of inmates to space. A hospital of defective construction may, by careful attention to these latter conditions, be rendered, even in a large town, comparatively healthy; and a hospital built on the most approved plan, and occupying the choicest site, may be rendered, in the highest degree, unhealthy by their neglect."[1]

Prof. Erichsen has called attention to a very important and generally recognized fact, that erysipelas is frequently produced by "*the contact of dead or putrescent animal matters with recent wounds.* . . . . In this way the disease is not unfrequently originated in hospitals by dressers going direct from the dead-house, and especially from the examination of the bodies of those who have died of diffuse inflammation, to the bedside of patients, without taking sufficient care to wash their hands or change their clothes. For this reason also it is of great consequence that the same instruments be not used for practising operations on the dead, and performing them on the living body. *Overcrowding of hospitals, and want of proper ventilation* in wards or rooms, are fertile sources of erysipelas, and of allied low inflammations; in fact, an outbreak of erysipelas might at any time be induced in this way amongst patients in all respects healthy and well cared for."[2]

Besides the morbid conditions which have been especially mentioned in the above as *having a marked predisposing influence in the production of erysipelas*, it should likewise be remembered that any disease which lowers the vitality of the patient generally renders him more susceptible to the action of *contagium vivum*. Furthermore, it is a well-recognized fact, that the *predisposition to erysipelas in some persons is so marked*, that it may be properly regarded as an *idiosyncrasy*, and this peculiar

[1] Prof. James L. Cabell, On Sanitary Conditions in Relation to the Treatment of Surgical Operations and Injuries. Virg. Med. Monthly, vol. ix. p. 538.

[2] Science and Art of Surgery, vol. i. p. 675, pub. in Phila. by H. C. Lea, 1878.

susceptibility to the disease may be either hereditary or acquired. The unfortunate subjects of this idiosyncrasy are sure to suffer from erysipelas on the slightest provocation, and no other form of septic disease appears as a substitute for it. The disease in these cases frequently reappears at short intervals and has been known to attack chlorotic women every month just at the period when the menses should make their appearance. Hoffman says: "This periodical nature of erysipelas has been observed in men. Larrey knew two male patients, one of whom used to be attacked with erysipelas twice a year at the time of the equinox; the other had only one attack annually, which was wont to happen in the beginning of the spring. My friend Mane, of Southampton, once informed me of erysipelas which was both periodical and universal, affecting a lady several times at intervals of two years."[1] In connection with the study of the etiology of erysipelas, the question has been frequently asked, if all the different forms of this disease take their origin from the same causes? It is now generally conceded that the reply must be in the affirmative, and that the various queries arising in connection with this subject and the answer may receive a satisfactory and logical solution. The simple fact, that cutaneous erysipelas is much more common than the other forms of this disease, unquestionably depends upon the greater frequency of wounds of this texture than any other membranous surfaces. Recent investigations have shown that this disease primarily consists of an irritation caused by the existence and rapid multiplication of living organisms within the lymph-vessels, and also occasionally within the lymph-cavities. Now, if this statement is correct, it will follow as a natural consequence, that the more abundant the lymphatic vessels and cavities, the greater will be the liability of that particular part to be affected with this disease, and the more active will be the erysipelas, *i. e.*, other things being equal. Furthermore, the liability of these parts to contract this disease should not only be greater; but the contagion having taken root, its course may reasonably be expected

[1] Cooper's Surgical Dictionary, p. 354, published in New York in 1846.

to be more active, since a given space of these parts will contain a greater number of living organisms. In studying this subject it should be remembered that the lymphatic glands and vessels are divided into the superficial and deep, and that the former are situated immediately beneath the integument and are those which are involved in cases of cutaneous erysipelas. Let us now examine our proposition and determine, as far as it is possible, how far the comparative frequency of these attacks corresponds with the distribution of the lymphatic glands and vessels. In this instance we shall limit our observation to *the lymphatics of the head* which include those of the cranium and face. We now cite from Sharpey and Quain's Anatomy for the purpose of showing the distribution of these lymphatics, etc.: "Commencing beneath the scalp, the lymphatics of the cranium join together so as to diminish in number whilst they increase in size, and are at length collected into an anterior and a posterior set, which follow respectively the course of the temporal and occipital arteries. The *temporal* set descend in front of the ear, some of the vessels passing through one or two glands usually found near the zygoma, whilst others enter those situated on the parotid gland; all of them terminate in the lymphatic glands of the neck. The *occipital* set of cranium lymphatics, accompanying the occipital artery, descends to the glands situated behind the ear (over the mastoid process of the temporal bone), and thence joins the superficial lymphatics of the neck. Within the cranial cavity, lymphatic vessels have been demonstrated in the pia mater and in the arachnoid membrane. None have been injected in the dura mater, nor have they been shown in the substance of the brain. The trunks of those derived from the pia mater pass out of the skull with the veins. The *superficial lymphatics of the face*, more numerous than those of the cranium, descend obliquely in the course of the facial vein, and join the gland placed beneath the base of the lower maxillary bone; a few of them in their descent pass through one or two glands situated over the buccinator muscles."[1]

[1] First Amer. from the fifth London edition, edited by Jos. Leidy, M.D., vol. ii. p. 57 *et seq.*

Dr. Henry Grey, F.R.S., says: "The *superficial lymphatics of the face* are more numerous than those of the head, and commence over its entire surface."[1] It should not be forgotten, in this connection, that the *lymphatic glands* found on the different parts of the *head* and *face* are few and very small, while those on the neck, on the contrary, are comparatively large and very numerous. How shall we now account for the *comparatively frequent attacks of cutaneous erysipelas on the face?* Are there not already sufficient facts before us to justify the conclusion, that these superficial lymph-vessels play an important part in the inoculation and spread of cutaneous erysipelas; and do not the lymph-glands, on the contrary, aid in arresting its further progress? We have hitherto spoken of the relation of the superficial lymph-glands, vessels, etc., to cutaneous erysipelas, only because the diseased phenomena which are limited to the surface of the body are more easily studied than those which are more deeply seated, while, at the same time, it must be readily admitted that the deep-seated lymphatic glands, vessels, etc., bear a similar relation to the deep-seated forms of erysipelas. The phlegmonous and œdematous varieties of erysipelas unquestionably take their origin from the same living organisms, which under other circumstances would have produced the cutaneous form of this disease. The deep-seated forms of erysipelas frequently owe their origin to a primary inoculation in the deep-seated lymph-vessels; but there are other cases in which the disease originates in the superficial lymph-vessels, and then travels through those which connect the two lymphatic systems. It is therefore possible for the slightest abrasion of the skin to produce the severest forms of this disease. It is, however, thought, that the character of this malady will generally depend upon the constitutional conditions, hygienic surroundings, and the point at which the contagion is introduced. The contagious character of erysipelas was formerly denied by many authors; but it is now *generally admitted*, and it may, like other con-

[1] Anatomy, Descriptive and Surgical. A new American from the fifth and enlarged English edition, p. 562.

tagious diseases under favorable conditions for its spread, become epidemic. It was also supposed, in former times, that erysipelas attacked more women than men; but more recent and careful investigations have shown that this disease is entirely impartial in this respect, and that its origin can generally be traced to other certain well-recognized etiological conditions. It may be here added, that a careful examination of statistics satisfies me that atmospheric changes, even as a *predisposing cause of erysipelas, excites no influence* over the origin or spread of this disease which is not common to most other contagious diseases. The *most important* atmospheric changes, cold and dampness, are those which interfere with ventilation, condensing the poison in the sick-room, lowering the vitality of all persons dwelling either in the mansions of the rich or the tenements of the poor, and thus effectually preparing for the spread of most contagious diseases.

Pathology.—The pathological lesions of erysipelas are conveniently divided for the purpose of study into local and general. The local pathological changes are those which occur in the *integument, subcellular, and cellular tissues.* The redness of the skin which characterizes this disease is undeniably due to a congestion of the parts, or, more properly speaking, to an overdistension of the cutaneous capillaries. Ribes and Cruveilhier endeavored to show that the venous capillaries were those principally affected in this disease, but it is now thought to be impossible for any pathologist to determine accurately in these cases, whether the chief congestion is greatest in the venous or arterial capillaries. L. J. Sansom has designated a particular variety of this disease by the *nom d'érysipèle veineux*, and this term is occasionally employed at medical clinics, although very rarely. Blandin believes that the chief lesions of this disease are found in the superficial lymph-vessels of the skin. If he is correct in his opinion, it is probably true that the initial inflammation of a cutaneous erysipelas starts in the small lymph-vessels of the integument and spreads to the adjacent tissues. We are not prepared to say that this theory is not entirely correct, but no pathologist has yet demonstrated it.

It is, however, undeniable that the lymphatic vessels in every case of this disease are more or less involved. Virchow says: "Every erysipelatous or diffuse phlegmonous inflammation has the peculiarity of early affecting the lymphatic vessels and producing swellings in the lymphatic glands."[1] We have ourselves observed, in the early stage of erysipelas, that the lymphatic glands are commonly swollen and painful, and we have also noticed in the course of the larger lymphatic trunks as they pass on toward the lymphatic glands, red lines indicating inflammation of the walls of these vessels and the adjacent tissues. It is regarded as probable that morbid action is going on in the lymphatic vessels of the skin at the same time that we recognize its progress in the lymphatic glands and lymphatic trunks, but it has thus far been impossible to distinguish the lesions in the lymph-vessels of the skin from those of the blood-capillaries. At the same time that the capillaries are over-distended with blood, the derma is slightly infiltrated with serum, which increases somewhat its thickness.

Vulpian found in an autopsy, the results of which he published in the *Archives de Physiologie*, in 1868, that the derma was only slightly thickened, but it was filled with leucocytes and pus-globules. Volkmann and Steudener observed the same condition, and made it known in 1869. They confirmed Vulpian by showing that the leucocytes appeared in the superficial layers of the derma and along the course of the congested blood-capillaries. Neither Vulpian, Volkmann, nor Steudener has even attempted to settle the origin or action of these leucocytes. Lukowsky and others have recently observed in the advancing line of the rash cutaneous erysipelas, that the lymphatic vessels and spaces of the skin are packed with micrococci, and that these are absent when the eruption is receding.

Cellulo-Cutaneous and Cellular Tissues.—These tissues are sometimes found infiltrated with serum and slightly reddened after death from erysipelas, showing that these parts have parti-

[1] Cellular Pathology, p. 200, translated from the second edition of the original by Frank Chance, B.A., M.B. Cantab., Phila., 1863.

cipated in the inflammation. There is generally some œdema in those parts when the skin is thin, and not supplied subcutaneously with adipose, especially in the eyelids, around the penis, and also in the lower part of the scrotum. It is less marked in other regions, and if it exists, it is not sufficiently decided to be observed during the lifetime of the patient. Although in very rare cases the œdema is a very marked feature of the disease, and hence the application of the term œdematous erysipelas.

General Lesions.—These are generally found in the blood and in the viscera. In many cases where careful autopsies have been made, the blood has been observed to be more fluid than usual, whilst in the same cases there were fewer heart clots. The lungs are quite frequently congested, and present all the peculiarities of that condition which has been designated as splenization, while the spleen is soft and diffluent. The arachnoid sometimes presents the pitchy state with a subserous infiltration which is characteristic of the first stage of meningitis. These different alterations in the blood and viscera are generally supposed to arise from the introduction into the circulatory system of septic material, and this opinion is strengthened by the fact that, in exceptional cases which have shown during the latter period of the disease marked symptoms of purulent infection, the autopsies have revealed metastatic abscesses in the lungs and liver.

Semeiology.—The first difficulty which presents itself under this head, arises from the fact that some authors apply the term erysipelas to every phlegmonous inflammation without regard to its origin or nature, while others employ it in a more restricted sense. A ready solution of this difficulty may be accomplished by dividing the disease into varieties which we will designate as true and doubtful. The term *true erysipelas* should be applied to all the forms of this disease, which by the general consent of authors and teachers have received the generic cognomen of *erysipelas;* and all the forms which are not included under the above nomenclature may be conveniently designated as *doubtful.* The following enumeration of symp-

toms will, therefore, only pertain to the different forms of true erysipelas. These symptoms may be conveniently designated as local and constitutional, and the disease itself may be divided into three periods, and called the *first, middle, and final.*

The First Period.—The first period of erysipelas is ushered in with a well-marked chill, similar to that of intermittent fever, and it is characterized by chattering of the teeth, trembling of the limbs, and the patient complains of a lively sensation of cold. During the chill there is commonly nausea, which is quickly followed by a free vomiting of gastric and bilious matters, while the patient suffers at the same time from a severe headache. The chill may last from half an hour to an hour, and is then replaced by heat of which the patient himself is sensible, while the surgeon detects it with his hand, and is shown by the thermometer to be from three to six degrees above the normal standard. The pulse now becomes strong and frequent, the breathing quick; there is a bitter taste in the mouth, and the tongue is furred. There is pain in the back, a general fatigue, and in the midst of all this, the greatest complaint is of the pain in the head. Thus far we have described no local symptoms, inasmuch as the disease at the commencement is entirely constitutional, and the intense fever is, without doubt, entirely due, as in intermittent fever and pyæmia, to the introduction into the system of a specific poison. It is commonly five or six hours before the first local symptom makes its appearance. At this time there may be detected a slight pain in the lymphatic glands nearest to the wound which is increased by pressure. These glands are a little swollen, but the pain is noticed even before the enlargement can be perceived. This order in the development of the symptoms in erysipelas is not always the same. There are cases reported in which the initial chill, nausea, vomiting, and headache were wanting. The pain in the lymphatic glands, I believe, *is a much more constant symptom, and very rarely if ever absent* in any case of traumatic erysipelas. It is commonly about twenty-four hours, sometimes a little more or less, before the characteristic *redness of the skin* makes its appearance, *but this symptom is never wanting*, and its

extent may vary greatly in different cases. The attendant pain in the reddened skin is similar to that caused by a *sunburn*.

The Middle Period.—This period commences forty-eight hours after the initial chill, or at the time, when the symptoms are sufficiently well developed to leave no doubt as to the nature of the disease. The chill has not returned, the nausea and vomiting have disappeared, but the fever continues. The pulse remains frequent, and the temperature high. The thermometer kept in the axilla about five minutes, shows a temperature of 100° to 105° Fahr. The pulse and temperature as in all fevers is higher in the evening than in the morning. The sleep is broken and extremely fatiguing. The thirst is unquenchable. The tongue is alternately moist and dry. There is a complete loss of appetite. There is more or less delirium, which in patients not accustomed to use alcoholic stimulants is generally tranquil, but boisterous and active in those who have long been accustomed to their use. Whilst these constitutional symptoms continue, the local redness becomes more pronounced, and is seen to extend from place to place around the wound. A peculiarity of this redness is that it quickly disappears under the pressure of the finger, but promptly returns when the finger is raised. Another peculiarity of this redness is, that it occasionally suddenly and entirely disappears, leaving behind a sharply cut line of demarcation, which is, however, more marked on persons of a light complexion than on those whose skins are dark. There are some cases in which there is observed a slight elevation in the integument at the border of the healthy and diseased tissues, which is more perceptible to the sense of touch than to the sight. There is also occasionally observed a jaundiced tinge, which does not, however, always prevent the line of demarcation between the diseased and healthy skin from being indicated by a difference in color. It has been further observed, that the reddened and diseased tissues, when pressed under the finger, do not generally convey the doughy sensation given by œdema. This sensation may be obscured or entirely effaced by infiltration of the subcutaneous tissues adjacent to the diseased parts. In addition to

the above it should also be remembered, that patients may not in all cases of erysipelas suffer from pain or heat in the diseased parts. Some persons, especially females, do not complain of these local symptoms; but suffer very severely from the general heat and malaise of the fever. The redness and other anatomical changes in the integument, which are peculiar to erysipelas, generally continue to extend a certain number of days. In some cases the progress of the disease is arrested for twenty-four hours, and then starts up anew. During the remission in the local manifestations there is an improvement in the constitutional symptoms, but with a renewal of the former there is also an exacerbation in the latter. These remissions and exacerbations may be repeated several times before the final convalescence makes its appearance. It will, therefore, be observed that the duration of this disease varies greatly, it some cases it terminates within six or seven days, and in other instances it continues as many weeks. In the majority of cases, the nature of the attack is supposed to indicate the character of the disease, *i. e.*, if the initial symptoms *are mild*, it is presumed the disease *will not be of long duration, or of unusual severity*, but there are many exceptions to this rule. It is the prolongation of the second or eruptive period which gives unusual length to *erysipelas ambulans*. In this form of the disease the eruption is gradually extending to new fields, while the redness is slowly disappearing from the points at which it began. It therefore follows, that the point of the original attack will be perfectly well long before the disease has completed its journey. This process continues until every part of the integument of the body has been affected. It will be observed that the *second period* constitutes a very essential part of the disease, inasmuch as it brings the patient to the commencement of his convalescence. This period in cases of simple erysipelas commonly terminates favorably, although it sometimes ends in death. The unfavorable symptoms which commonly announce the approach of death are generally ushered in about the twelfth or fifteenth day of the disease. The erysipelatous redness and its accompanying pathological changes now begin to spread rapidly. The tongue

is no longer alternately dry and moist, but is now deeply furred and continuously dry. The patient is attacked with diarrhœa, the teeth and lips are covered with sordes, there is constant delirium, the pulse is feeble, the face is haggard, occasionally there is a slight icteric hue of the complexion, bed-sores make their appearance over the sacrum or about the trochanters, etc. The general state of the patient resembles that seen in grave cases of typhoid fever, and it terminates like them in death; thus affording additional proof in support of the opinion that erysipelas is purely a septic disease.

The Third Period.—This stage of the disease is characterized by an improvement in all the constitutional symptoms. The pulse becomes daily less frequent, the heat is diminished, the temperature is steadily descending toward the normal standard, the respirations are less rapid, the tongue is cleaning, the light layer of whitish epithelium which had commenced to cover the gums has disappeared by the tenth or fifteenth day, the appetite becomes natural, and the patient is able to sleep. At the same time the redness ceases to extend, is fading out slowly, more rapidly at certain points than at others, particularly at those points at which it first commenced. It entirely disappears in the space of eight or ten days, and is replaced by a desquamation similar to that of scarlatina. Having now outlined the symptoms which are commonly observed in cases of simple erysipelas, it still remains for us to enumerate those which are seen in connection with the different forms of this disease. The variations of these symptoms are found in the local manifestations and constitutional disturbances.

Variations in the Local Symptoms.—Frequently at the commencement of the disease within the limits of the first and second periods, there are occasionally observed red lines, which start from the wound and extend toward the enlarged and painful lymphatic glands. These lines are commonly observed several days before the appearance of the erysipelatous eruption, and are the visible effects of an inflammation, which had its origin in the lymphatic trunks, and which has involved secondarily the adjacent tissues and overlying integument, *i. e.*, the erysipelas

is accompanied by an angeioleucitis or lymphangitis. It is also true that every case of erysipelas is accompanied with lymphangitis, since in all cases there is more or less adenitis which probably extends to the lymphatic vessels of the skin. Nevertheless it has long been customary to discriminate between adenitis, lymphangitis, and erysipelas; and the clinical advantages arising from this discrimination must be apparent to every surgeon, when it is remembered that the two first mentioned diseases, because of their mildness, sink into comparative insignificance when compared with erysipelas, which is justly regarded as a grave disease. The former diseases are commonly unattended with constitutional symptoms, while erysipelas is *always* accompanied by more or less severe constitutional disturbances. There are certain questions connected with the etiology of these three morbid conditions which are still unexplained, and it remains yet to be shown why the introduction of the *same poison* into the *same parts* of the body, in one instance *will be followed by adenitis*, in the *second case by lymphangitis*, and in the *third by erysipelas*. Lest our proposition may be criticized, we will here admit that it has never been actually demonstrated that the poison in these cases is identical; but there are certainly strong circumstantial evidences in favor of the proposition. *Are these diseases essentially the same in character*, differing only in severity, as is supposed to be the case in the different forms of diphtheria and scarlatina? Should this question receive an affirmative answer, then it must be readily admitted that our etiological query bears a similar relation to all these conditions. Every intelligent husbandman recognizes the fact, that good seed does not insure an abundant yield; but that the quantity produced will also depend upon the soil, moisture, heat, etc., as necessary factors for the reproduction of that which was sown, and why should it not be admitted, that certain physiological conditions are equally essential in the development of disease germs? If we accept this interpretation of nature's laws, and their application to morbid processes, it may then be quite possible for us to explain why the *same diseases differ so widely in severity and other characteristics* in different

cases. The same theory would likewise be more or less applicable to the explanation of the contagiousness of disease which is a problem connected with the subject now under consideration. It is now generally admitted that erysipelas is both a *contagious and epidemic disease*, but neither *adenitis* nor *lymphangitis* possesses either of these characteristics.

Bullate, Phlyctenoid, and Pemphigoid Erysipelas.—During the first stage of the second period, the redness of erysipelas is frequently specked here and there with vesicles, which vary greatly in size and likewise in the appearance of their contents. The serous effusions which take place from the inflamed surface elevate the cuticle into larger or smaller vesicles or bullæ, which resemble those produced by a blister. The contents of these bullæ or vesicles are sometimes nearly colorless; but they frequently contain a soft, yellow, jelly-like deposit. In other cases the contents consist of a thin pus or bloody serum. The fluid contents of these vesicles which were at first transparent, soon lose their clearness, becoming thicker, opaque, and whitish or yellowish. The cuticle gives way, the fluid escapes, and incrustations form which soon fall off, leaving the skin sound, or an ulcer may form on the site of each vesicle. The vesicles have no unfavorable signification in connection with a case of erysipelas. They do not apparently change the nature of the disease or increase the danger.

Œdematous Erysipelas.—Œdema is one of the common characteristics of every form of erysipelas, but it is only in certain cases that it becomes the most important pathological condition of the disease. This disease commonly occurs in *dense cellular* tissues, and within the parts which are commonly well supplied with adipose; the thigh being its most favorable point of attack. The erysipelas having gained a foothold here, is sometimes accompanied by a very pronounced œdema, which greatly exceeds the limits of an ordinary infiltration. Old age or an enfeebled constitution is the common predisposing cause of the disease. It may generally be expected to readily disappear when the patient is placed in the recumbent position, and receives the proper attention.

Ecchymotic Erysipelas.—This term has been applied to a rare form of erysipelas, in which the characteristic redness of the skin is mottled by a bloody infiltration, which gives to these spots a blackish or brownish color. This peculiarity of disease occasionally shows itself when an old or enfeebled person is attacked by erysipelas, and it arises from the rupture of some of the over-distended capilliaries of the integument. These purpuric spots are not always limited to the erysipelatous patches, but they occasionally appear over the integument of the whole body. There is very little or no importance to be attached to the purpuric complications of erysipelas.

Phlegmonous Erysipelas.—This disease was described by Dupuytren under the name of "*diffuse phlegmon.*" Under the name of phlegmonous erysipelas there are comprised two conditions, one commonly ends in gangrene, and the other in the formation of an abscess. The former condition we shall designate by the term "*diffuse phlegmonous erysipelas;*" and the latter by the name of "*circumscribed phlegmonous erysipelas.*" In the former variety, the phlegmasia occupies at the same time a large surface of the integument and the adjacent subcutaneous tissues. This morbid condition shows a tendency to suppuration and generally ends in *gangrene with the formation of large, white, soft sloughs.* The latter condition is characterized by a *circumscribed phlegmonous erysipelas,* which involves a large reddened surface of the integument and a circumscribed inflammation tending to suppuration at certain points in the connective tissues which are beneath and adjacent to the diseased skin, but with *no tendency* to *gangrene* or the formation of *sloughs.* The *diffuse phlegmonous* erysipelas is described by many authors under the name of "*diffuse phlegmon,*" and by some, by that of phlegmonous erysipelas. This disease in practice presents itself in two forms, the one more benign, more moderately pyretic, and in which the chief pathological lesions are the suppuration and gangrene. The *other form* of *this disease* is more *pyretic* and *more grave.* The lesions of the connective tissue, in the second form, are preceded and accompanied by a much larger reddened space, thus enlarging the limits for

suppuration, in which the erysipelatous elements play the principal part. In the first variety of *diffuse phlegmonous erysipelas* there is only a *diffuse phlegmon*, and in the second form, there is *diffuse phlegmon* with *erysipelas* or *diffuse phlegmonous erysipelas*. We have now reached the consideration of the *circumscribed phlegmonous erysipelas*, which is characterized by the existence of a phlegmonous inflammation of greater or less size, and which terminates rapidly in a circumscribed abscess. During the first few days there is observed little of importance; but from the eighth to the fifteenth day, there is discovered at certain points, generally along the lymphatic trunks, a slight induration, which soon becomes very painful and increases rapidly. The skin covering the induration now becomes very tense and glossy. These symptoms are the prelude to prompt suppuration. The pus liberated by a spontaneous or artificial opening is thick, laudable, not mixed with sloughs or gangrenous shreds. Frequently there is only a single abscess, but sometimes several form at certain distances from each other. This form of the disease is essentially mild, although phlegmonous in its character. The abscesses having been opened, the patient soon recovers, and every trace of the erysipelas soon disappears. In those cases in which abscesses have followed septic diseases such as scarlatina, there may be developed only a single abscess, but in the majority of instances there are several; and it occasionally happens that abscess follows after abscess until the patient's strength is exhausted and death comes to his relief. My investigation of *phlegmonous erysipelas* has left a strong impression on my mind, that the nomenclature of this subject is very loose and unsatisfactory. It may, therefore, be in order to ask what is the difference between an ordinary case of cellulitis and one of *circumscribed phlegmonous erysipelas*. Mr. Erichsen says: "That the diffuse inflammation of the areolar tissue, whether it be limited to a finger, or implicate the areolar tissue of half the body, is a variety of erysipelas affecting this texture primarily, and the skin secondarily, there can be no doubt. The points of resemblance between cellulitis and erysipelas have been well shown by Nunneley. Not only are the

local effects precisely the same in the two diseases, the swelling, tension, infiltration of pus, and formation of gangrenous shreds and sloughs, but the constitutional symptoms, though varying perhaps in degree, present no difference as to character. The results also are identical, there being the local impairment of structure, the same tendency to involve parts at a distance, and to the formation of secondary abscesses. These two forms of disease occur in the same constitutions, in the same states of the atmosphere, and in the same situation; one may produce the other; and lastly, the same treatment is required for both."[1]

This opinion expressed by Erichsen is not apparently shared by Gant, who says: "*Phlegmonous inflammation* contrasts with phlegmonous erysipelas in certain particulars—and which determine their diagnosis, a question of much importance. Circumscribed and limited infiltration of the subcutaneous cellular tissue with coagulated lymph is the essential pathological condition peculiar to phlegmon. It is an inflammation of the *cellular texture primarily*, the skin being only secondarily involved; whereas phlegmonous erysipelas selects first the skin, and then involves the subcellular tissue. *Coagulating lymph*, rather than serum is effused in phlegmon; the consequent swelling is, therefore, *circumscribed* and *limited*, instead of being diffused and widespreading; it is also *brawny in the first instance*, that of phlegmonous erysipelas becomes so gradually; lastly, respecting the issue of these two species of inflammation, the erysipelas is prone to slough while that of phlegmon is liable only to this termination."[2]

Having already presented the characteristic symptoms of erysipelas it now remains to mention those which belong to phlegmon. In those cases of phlegmon, or phlegmonous erysipelas in which the disease first makes its appearance in the skin, the pain is commonly of a burning or pungent character, but when it has extended deeply into the cellular tissue it

[1] Science and Art of Surgery, vol. i. p. 679. Revised by the author from the seventh and enlarged English edition, Phila., 1878.

[2] Science and Practice of Surgery, vol. i. p. 288. Second revised edition, Phila., 1878.

is apt to assume a throbbing nature which may be regarded as a prelude to the formation of pus. The swelling in the diseased parts is at first slight, but it increases more or less rapidly until the skin has become very tense, and the limb very nearly or quite twice its natural size. The disease may be expected in favorable cases to assume a better aspect between the eighth and fifteenth days, but should the patient go on from bad to worse during this period an unfavorable termination may be expected. It it only just to add in this connection that in every case of cellular or cellulo-cutaneous inflammation, it may be properly anticipated, that the severity of disease will be represented by the intensity of the symptoms; and, furthermore, that the pathological lesions should be regarded as the trail left behind by the enemy, and that its width, depth, and other characteristics represent the force of a destroying agent. It is, therefore, apparent to every careful observer; that, since the term phlegmonous erysipelas is applied to a considerable variety of morbid conditions; that, consequently the symptoms and pathological lesions in different cases will be found to vary widely. It is thought, however, that the principal difference in the symptoms will be found in the degree of their intensity, while the pathological changes may be so slight, as to be of little importance, or so severe as to destroy life, or permanently maim the patient. These important changes have been presented by Prof. Erichsen in the following words:—

"If, under the influence of proper treatment, and in a tolerably healthy constitution, the inflammation subsides, resolution takes place, with a gradual abatement of all the symptoms. If, however, as usually happens, the disease moves on to more or less sloughing or suppuration of the part, no increase of the swelling, pain, or redness takes place, but, on the contrary, some diminution of these signs may occur, and thus give rise to a deceptive appearance of amendment. The skin becomes darkly congested, and the part, instead of being tense and brawny, has a somewhat loose, soft, and boggy feel, communicating a semi-fluctuating, doughy sensation to the fingers. This change from a tense brawny state to a semi-pulpy condition indicates the

formation of pus and slough beneath the integument, and occurs without any material alteration in the size, color, or general appearance of the parts, but can only be detected by careful palpation; hence the surgeon must daily examine with his own fingers the state of the part, and neither trust to the reports of others, nor to the general appearance of the diseased structures, for a knowledge of the probable condition of the subjacent tissues. If an incision be now made into the affected part, the areolar membrane will be found loaded with an opalescent fluid distending its interstitial loculi, but not flowing from the wound: the retention of this fluid gives a gelatinous appearance to the sides of the incision, which rapidly degenerate into slough and pus. If the alteration in structure have advanced to a stage beyond this, the areolar tissue will be found to have been converted into dense masses of slough, bathed in thin and unhealthy ichorous pus; these sloughs have not inaptly been compared in appearance to masses of decomposed tow, of wet chamois leather or to the membranes of an embryo a few months old. Whilst these changes are going on below the surface, the skin, at first congested, becomes somewhat paler, and assumes a white or marbled appearance, rapidly forming into black sloughs, and being undermined to a large extent by large quantities of broken-up areolar tissue and of ill-conditioned pus, without any appearance of pointing, however extensive the subcutaneous mischief may be. These destructive changes expose muscles, faciæ, and bloodvessels, and may induce necrosis of the bones or destroy the joints. They occur most readily in those parts of the body that possess the lowest degree of vitality, and hence are more common in erysipelas of the legs than in the same affection of the scalp. If the patient recover, there will be tedious cicatrization of the deep cavities that are left, or considerable œdema, often of a solid character, a kind of false hypertrophy of the parts, which may continue for some considerable time. In other cases, there may be such extensive local destruction or gangrene of the soft tissues, with exposure and death of the bones, or suppuration of the joints, that amputation of the limb may be required to save the patient's life. No

operation of this kind, however, should ever be practised for the effects of erysipelas, unless they be strictly localized, and without tendency to spread; nor until specific constitutional fever has been completely removed, except such as is of a hectic character, and dependent on the exhausting influences of the suppuration and disorganization of the tissues."[1]

The treatment in all these conditions requires that the surgeon in every case of a phlegmon should watch carefully for the appearance of fluctuation, in order that he may liberate the pus, relieve the tension of the parts, and thus prevent unnecessary constitutional disturbance. It may likewise be necessary to support the patient with tonics, nutritious food, and improved hygienic surroundings; and, as an adjuvant to these remedial agents we may require an anodyne to relieve the pain and prevent an unnecessary loss of nervous energy.

Gangrenous Erysipelas.—We have already called attention to a form of gangrene which occurs in connection with *phlegmonous erysipelas*, but this disease bears little or no pathological resemblance to that which we are about to describe. The term gangrenous erysipelas is only applied to morbid conditions in which the skin becomes gangrenous and sloughs without being accompanied with phlegmon. The predisposing cause of this disease is an enfeebled constitution which may arise from age, disease, or dissipated habits. Hereditary diseases are known to act as predisposing causes; and, consequently, cachectic infants of scrofulous and syphilitic parents are frequently among its victims. It has been observed to attack paupers, seemingly from preference, but it is probable that the true explanation of this matter will be found in their vicious habits and consequent proneness to disease. *Gangrenous erysipelas* is not commonly a primary affection, but generally occurs as a complication of some other disease. It is always preceded by very high fever, the patient is very sick, thus showing that the disease arises from constitutional and not from local disturbances. There

[1] Science and Art of Surgery, vol. i. p. 677 *et seq.* American edition, from the seventh and enlarged English edition, Phila., 1878.

have been recognized two varieties of this disease which differ widely in their local peculiarities. The first form is ushered in with the usual constitutional symptoms which are followed in due time by the local manifestations, such as dusky redness of the skin, which does not disappear under pressure, slight elevation of the temperature in the parts, slight pain, and a moderate circumscribed doughy swelling. There commonly appears between the fifth and tenth days on the reddened surface of the integument one or more black spots which remain moist, cold, and without sensation. The skin covering these spots may be soon distended with an ill-conditioned sanguinolent serum, thus producing phlyctenæ; but whether the latter change takes place or not, these black gangrenous spots soon slough. The immediate causes on which these pathological changes are dependent are not well understood. However, the appearance of the sloughs is always attended by an aggravation of the constitutional symptoms. The fever becomes more intense, the tongue drier, the prostration increases rapidly, and death soon brings relief to the patient's sufferings. The *second variety of gangrenous erysipelas* is characterized locally by the *appearance of the black sloughs without previous redness of the integument.* In this respect, this form of the disease resembles spontaneous gangrene, but it differs from it, inasmuch as the latter is *never attended with fever or other constitutional symptoms*, while gangrenous erysipelas always commences with these manifestations. Furthermore, the sloughs in gangrenous erysipelas are always surrounded by an erysipelatous redness of the skin; but the redness of spontaneous gangrene *appears later and spreads very slowly*. The sloughs in gangrenous erysipelas cease to enlarge after a few days, but the erysipelatous redness, on the contrary, continues to extend. This form of erysipelas has been known to attack the scrotum more frequently than any other part of the body, and the diagnosis is here rendered somewhat more difficult because of a certain degree of similarity of the local symptoms of this disease, to those produced by urinary infiltrations. In formulating a differential diagnosis, the surgeon is greatly aided by remembering that urinary infil-

tration does not generally occur without being preceded by urethral disease; and, likewise, that here the formation of the slough is always anticipated for a longer or shorter period by œdema and redness which arises from the infiltration of the parts with urine; but, on the contrary, in cases of gangrenous erysipelas the *first* local manifestation of the disease is the appearance of the black spots in the integument. It has been supposed that *gangrenous erysipelas* of the scrotum has been mistaken, in some cases, for the malignant pustule; but the infrequency with which the latter disease occurs in these parts, together with the tumefaction and severe pain in the inguinal lymphatic glands during the early stage of its development, and likewise that this disease subsequently limits itself to a more restricted surface than gangrenous erysipelas, must be accepted as important points in establishing a differential diagnosis.

L. Gosselin informs us, as the result of his observation, that this variety of *gangrenous erysipelas* is much less grave than the other form of this disease. The chief difference in the result of these two varieties of this disease he thinks may be due to the thinness of the skin which is attacked in the latter instance, and the facility with which the nutrition of the integument is impaired by an active congestion, rather than to the severity of the constitutional contamination which certainly plays an important role in the former morbid condition. The recoveries in the second variety of gangrenous erysipelas occur in about the same proportion as in the ordinary traumatic erysipelas. He adds, three of my patients have recovered after having lost a portion of the substance of the scrotum, a loss which was followed by a more or less tardy cicatrization. In two of these cases the loss of substance did not exceed four centimetres in diameter. In the third, which he saw at the Charity Hospital in 1870, the loss was more than eight centimetres, the testicles were left entirely naked, and appeared exactly the same as in cases of sloughing after urinary infiltration. Nevertheless recovery took place and the testicles were finally covered with more or less cicatricial tissue, while the integumental borders of

the wound were approximated as nearly as possible by the methodical application of strips of adhesive plaster.

Special Forms of External Erysipelas.—It has been and is still the habit of many authors to mention specially, under this head, several forms of erysipelatous inflammation; but, inasmuch as they present for consideration essentially the same etiological questions are manifested by the same symptoms, are followed by the same pathological changes, and require the application of the same principles in their treatment as the varieties which have been already studied, it would seem unnecessary to devote much space to them here. Prof. Erichsen has mentioned, under this head: "Erysipelas of newly born infants," "Erysipelas of the Orbit," "Phlegmonous Erysipelas of the Lips and Side of the Face and Neck," "Diffuse Cellulitis of the Submaxillary Region," "Erysipelas of the Pudenda," "Erysipelatous Inflammation of the Fingers," etc.

The Erysipelas of Newly-Born Infants is occasionally met with in the lying-in wards of hospitals; and also under other circumstances, when the child is subjected to the predisposing and exciting causes of the disease. It commonly appears a few days after the birth of the child on the abdomen and genitals, extends rapidly over the body, and commonly terminates in gangrene and death. There is little which can be done in the way of medication, but it is frequently necessary to attempt to improve the hygienic surroundings and relieve the little patient from unnecessary suffering.

Erysipelas of the Orbit.—This disease does not occur as a primary affection, but generally arises by the extension of erysipelas from the adjacent parts. The chief danger of this disease is due to its extension to the meninges of the brain and the brain substance. Prof. Erichsen says: "It commences with a violent deep-seated pain at the base of the orbit, the conjunctiva becomes injected and ecchymosed, the eyelids are greatly swollen, red, and œdematous; the eyeball protrudes, and the vision is impaired or altogether lost. Symptoms of cerebral inflammation now set in, and the patient becomes delirious and often sinks comatose. The *treatment* consists of fomentations

with early and free incisions into the orbit, made by pushing a lancet flatwise between the eyeball and the orbital walls, through the inflamed conjunctiva, the eyelids having been previously everted. In this way the inflammatory effusions and pus may be evacuated. Destructive abscesses of the orbit, possibly of an erysipelatous origin, occasionally occur in the puerperal state, requiring when practicable, the free evacuation of the pus, in the way just mentioned."[1]

Phlegmonous Erysipelas has already been carefully considered; and since the disease is essentially the same, whether it occurs in the head, face, neck, or lower extremities, it therefore seems entirely unnecessary to spend more time here in a recapitulation of what has already been said. It is undoubtedly true that the danger of erysipelas to the life of the patient commonly depends on the severity and locality of the disease. I can now recall a case of cellulo-cutaneous erysipelas arising from the contamination of a slight abrasion of the skin on the neck, which terminated fatally within forty-eight hours by an extension of the disease to the larynx and the production of œdema of the glottis.

Erysipelas of the Pudenda.—This disease is occasionally observed among children who are surrounded by bad hygienic conditions, in whom cleanliness is neglected, and who do not receive the proper food. It generally assumes a phlegmonous character, which is promptly followed by sloughing, and it may prove fatal by inducing peritonitis or exhaustion.

Erysipelatous Inflammation of the Fingers.—The propriety of classifying *whitlow* as an erysipelatous inflammation of the fingers, may be justly questioned, as well as the declaration that every form of cellulitis should be regarded as an erysipelatous inflammation, since there are *certainly good reasons for believing that every form of true erysipelas is a specific inflammation arising only through inoculation*, and in these particulars it strongly resembles the vaccine disease.

[1] Science and Art of Surgery, vol. i. p. 685, Amer. edition, from the seventh and enlarged English edition, Phila. 1878.

Internal Erysipelas.—This term is applied to a *specific and diffuse inflammation* of the mucous and serous membranes; and the disease has been studied in the fauces, larynx, arachnoid, and peritoneum.

Erysipelas of the Fauces.—It is believed that this disease may arise in these parts in connection with a wound, or that they may become secondarily involved by the spreading of erysipelas from the head and face to the mucous membranes of the mouth and throat. In the latter case the diagnosis is very easily made, but under other circumstances there is a wide field for speculation in the differentiation of the various varieties of inflammation which affect these parts. The symptoms observed in this disease are a bright crimson or scarlet color of the fauces, swelling and thickening of the soft palate and uvula, some huskiness or complete loss of voice, and frequently some croupy symptoms. There is also a mild constitutional fever, hot skin, and quick pulse. This disease is actively contagious, and frequently occurs among the attendants who are caring for those suffering with other varieties of erysipelas. It is also characterized by the same peculiarities in these parts as in other portions of the body. It may remain limited to the palate and fauces, or extend in any direction. It sometimes extends upwards through the nares, out of the nostrils, and thus spreads over the face and head, while in other cases it passes downward to the gastro-intestinal membrane, but it more frequently implicates the larynx.

Treatment.—It is claimed that the *best results* in treatment are obtained by sponging the inflamed parts with a strong solution of *nitrate* of *silver*, and the use of such constitutional remedies as seem to be indicated by the exigencies of the case. Should this disease go on to sloughing, its proper management will then require frequent and thorough cleansing of the diseased parts, the use of disinfecting gargles, suitable tonics, and a supporting diet.

Erysipelatous Laryngitis.—This disease is an extension of an erysipelatous inflammation from the fauces to the mucous membrane, and the loose submucous areola tissue external to and

within the larynx, resulting in an extensive œdematous infiltration with sero-plastic fluid, which, by obstructing the rima glottidis may suffocate the patient. In consequence of the marked tendency to œdema in this disease, it has been designated by some as "*œdematous laryngitis.*" Dr. J. Solis Cohen thus describes *erysipelatous laryngitis*: "It is usually associated with erysipelas of the tongue, palate, and pharynx, by which it is sometimes preceded. It sometimes occurs as a metastasis of external erysipelas, which subsides as the internal structures are engaged. It may occasion fatal œdema of the larynx. The inflammatory process soon terminates in extensive suppuration, diffuse abscess, and sloughing, involving intra-laryngeal and peri-laryngeal structures, as well as the epiglottis and other cartilages, and the trachea."[1]

Erichsen remarks that: "The progress of this œdematous inflammation of the mucous membrane and loose submucous tissue in these situations, is often amazingly rapid, the swelling being sufficient to induce suffocation at the end of thirty-six or forty-eight hours, or even sooner. If the patient be not carried off in this way, there will be a great tendency to suppuration and sloughing of the affected tissues, leading perhaps eventually to death from absorption of pus and low constitutional fevers."[2]

Pathology.—The pathological changes which have been reported in these cases, may be described under two heads, and arise from the erysipelatous laryngitis *itself*, or from this disease when complicated with pyæmia. The changes which have been observed in the uncomplicated cases are essentially *local*, while those which have arisen from a pyæmic complication, are not limited to the parts which were originally diseased, but are found in other portions of the body. As might be anticipated, in the first class of cases which have terminated fatally, the submucous areolar tissue of the fauces, that at the base of the epiglottis, and especially that which enters into the arytæno-

[1] Diseases of the Throat and Nasal Passages, Cohen, p. 436, second edition, W. Wood & Co., N. Y., 1880.

[2] Science and Art of Surgery, vol. i. p. 690, American edition, from the seventh enlarged English edition, Phila., 1878.

epiglottidean folds, and that covering the posterior part of the larynx will be found distended with serum or a puriform fluid. Erichsen says: "This infiltration reaches to the rima of the glottis, and, extending into the interior of the larynx gives rise to such swelling that its cavity is nearly obliterated. Great as the swelling may be, however, in all these parts, it never spreads below the true vocal cords. This fact, which is very important, is explained by the mucous membrane coming close into contact with, and being adherent to, the fibrous tissue of which these structures are composed, without the intervention of the submucous areolar tissue."[1]

Prof. Gross, who had an excellent opportunity to study the pathological changes in this disease, clearly describes a condition which was unquestionably due to pyæmic complications. He says: "If the patient survived any time, profuse suppuration, and sometimes even extensive sloughing occurred; abscesses formed in various regions of the body; and after much suffering, the patient either recovered or died from exhaustion. In some of the persons whom I attended there was extensive ulceration of the tonsils and arches of the palate; and, in several, complete destruction of the parotid gland of one side. In one case, almost the whole of the occipital bone was stripped of pericranium. Dissection disclosed deep engorgement of the lungs, accompanied in many cases by inflammation of the bronchial tubes, and even of the pulmonary parenchyma, and by effusion of serum, or of serum and pus, in the pleura and arachnoid sac. The abdominal and pelvic viscera were generally sound, except in lying-in females, who usually exhibited high evidence of peritonitis, metritis, and phlebitis. In one instance, which occurred quite early in the epidemic, the immediate cause of death was a large metastatic abscess in the left lung, the erysipelas being seated in the corresponding leg."[2]

Symptoms.—The enlargement and tenderness of the lymphatic glands behind the angle of the lower jaw are commonly

[1] Erichsen's Science and Art of Surgery, vol. i. p. 690. American from the seventh enlarged English edition, Phila., 1878.

[2] System of Surgery, vol. i. p. 549 *et seq.*, fourth edition, 1866.

one of the earliest symptoms observed by the patient. This symptom is soon followed with some pain and difficulty in deglutition, dyspnœa, disphonia, nausea, vomiting, and delirium. An examination of the fauces shows it to be deeply reddened, and, at the same time, more or less tumefied. The difficulty in breathing is apt to increase rapidly, and may speedily threaten, or even destroy the life of the patient. The chief difficulty in these cases is felt during the attempts at inspiration, because the swollen parts above the opening of the larynx fall together like valves, while expiration is comparatively easy, since the obstructing parts are easily separated by the air coming from below.

Diagnosis.—Dr. Cohen remarks: "Evidence of external erysipelas, or of erysipelas of the mouth and pharynx, are usually necessary to establish the diagnosis. But few laryngoscopic examinations have been made in the disease. The interior of the larynx is described as red, lustrous, and tumefied with more or less manifestation of submucous infiltration. The image, then, is simply that of laryngitis, and presents nothing characteristic, like the demarcating line of cutaneous erysipelas."[1]

Prognosis.—The prognosis in erysipelatous laryngitis is never flattering, but on the contrary is commonly grave; however the prognostication in each case must be chiefly based on the severity or mildness of the disease as indicated by the symptoms, the power of the patient to resist morbid impressions and the hygienic surroundings of the case.

Treatment.—The treatment should be both local and constitutional. The local treatment should commence with the scarification of the parts, as recommended by Prof. Erichsen, and be promptly followed by the inhalations of steam from hot water. In addition to these measures, a large number of leeches may be applied over the swollen lymphatic glands behind the angle of the lower jaw; the fauces, pharynx, and upper portion of the larynx should be well sponged with a strong solution of nitrate of silver, carbolic acid, etc.; an emetic may be employed in some

[1] Diseases of the Throat and Nasal Passages, Cohen, p. 436 *et seq.*, second ed., New York, 1880.

cases to remove the mucus from the throat, but should the dyspnœa continue to increase, tracheotomy should be *promptly performed*, without waiting until the patient is in *articulo mortis*. This operation is recommended by Drs. Gross, Erichsen, Ryland, Gibb, and others; although condemned by Porter, and we are informed by Dr. Cohen, that in his researches into the literature of this subject, he has been unable to discover that a single life has ever been saved by it. Blisters, mercurial inunctions, and detergent gargles have likewise been employed in this disease. The constitutional treatment consists in the judicious use of purgatives for the purpose of keeping the bowels properly opened, while tonics, stimulants, and anodynes are also advantageously employed to meet the various indications as they arise. Quinine, iron, brandy, and morphine are properly classed among the most potent agents in the management of this disease.

Erysipelas of the Serous Membranes.—It is unquestionably true, that an erysipelatous inflammation does occasionally attack the serous membranes, arising here from the same causes which produce it in cutaneous surfaces, but owing to the fact, that the existence of the disease, in the former case, is not indicated by any thoroughly characteristic symptoms; therefore we can never be assured of the correctness of our diagnosis, except in those cases where the disease has extended from the integument to these membranes. Prof. Erichsen believes that erysipelas is frequently met with in the arachnoid and peritoneum. He adds: "These, like all other serous membranes, are liable to two distinct forms of inflammation: one, which is sthenic, having a tendency to the formation of plastic lymph; the other, which is diffuse or erysipelatous, being always accompanied by the exudation of a plastic unorganizable material."[1]

Erysipelatous or Diffuse Arachnitis.—This disease generally arises in connection with a wound of the head and an erysipelas of the scalp. Its existence is indicated by pain in the head, a

[1] Science and Art of Surgery, vol. i. p. 691, American edition from the seventh enlarged English edition, Phila. 1878.

flushed countenance, bright staring eyes, and low muttering delirium, followed by a comatose condition speedily terminating in death, while the constitutional symptoms are those of a low irritative fever. *The post-mortem examination* reveals pathological conditions which are common to arachnitis. The *arachnoid* and pia mater are fully injected with blood, thus establishing a complete network of vessels over the surface of the brain, which is also somewhat congested while the ventricles are distended with a reddish colored serum. In the more chronic cases, the inflamed arachnoid is generally covered with a layer of opaque puriform lymph of greenish-yellow color and slimy consistence.

Erysipelatous or Diffuse Peritonitis.—This disease may arise in connection with any open wound involving the peritoneum, but it is more apt to make its appearance in those cases when the patient by reason of age, debility, or other constitutional conditions, is brought into a state favorable to its development. In this class of subjects, it may make its appearance after an operation for hernia. The symptoms of erysipelatous peritonitis are commonly passive rather than active. The chief symptoms are an obscure pain diffused over the abdomen, tenderness on pressure, an anxious and depressed countenance, a small and rather hard pulse. Prof. Erichsen adds: "There may be heat of the skin, but it is a peculiar feature of this form of the disease that the patient may die without any elevation of the temperature of the body. On examination after death, the subperitoneal areolar tissue is found injected, the peritoneum opaque in parts, covered with filmy patches of grayish lymph, and usually containing a large quantity of opaque, dirty-looking turbid fluid, mixed with shreds and flocculi of lymph. This, though closely resembling pus in appearance, is serum with lymph intermixed, and is peculiarly acid, acrid, and irritating. It is this form of peritonitis that is especially dangerous to dissectors, inoculation of the fingers with any of this fluid being often productive of the most serious and even fatal consequences."[1]

[1] Science and Art of Surgery, vol. i. p. 691, American edition, from the seventh enlarged English edition, Phila. 1878.

Relapsing Erysipelas.—It has occasionally happened that erysipelas has returned on the fifth to the tenth day after its disappearance, although the patient seemed to be progressing favorably during this period of convalescence. In fact, the patient's suffering had disappeared, his appetite had returned, and he had commenced to regain his strength, when suddenly he was seized with a violent chill and nausea, severe headache, high temperature, and a frequent pulse. These initial symptoms are soon followed by the characteristic redness of the integument which appears in the same region, and, in fact, covers the same space which had been previously involved in the erysipelatous inflammation.

L. Gosselin has observed the following in regard to relapsing erysipelas:—

1. The redness appears early and extends very rapidly within the first twenty-four hours; it generally covers nearly the entire surface, which had been previously involved in the disease, and which had required several days to spread over.

2. The period of resolution is also short. The fever and redness commonly entirely disappear within four or five days.

3. The relapsing erysipelas is generally mild and commonly terminates in a prompt recovery.

Erysipelas characterized by Typhoid Symptoms.—This form of erysipelas was first studied by Dr. Fenestre, a French physician, in 1861, and it will be observed that the symptoms which he described as characterizing this disease are essentially those of typhoid fever. In this disease there is not only a frequent pulse and high temperature, which continue without remission, but the tongue is dry, and the teeth and lips are soon covered with sordes. The patient is rapidly prostrated, in some cases he is drowsy, while in other instances he is continuously delirious. He is generally attacked on the sixth or seventh day with diarrhœa, the movements of the bowels being frequently involuntary, the bed is wet with urine, which also in some cases escapes involuntarily, while in others it may be retained in the bladder, necessitating the use of the catheter. A little later in the disease, the abdomen becomes distended

with flatus, and the skin assumes an icteric hue. The two last symptoms generally indicate a fatal termination.

Dr. L. Gosselin has reported several cases in which distension of the abdomen and the icteric hue did not occur, but there had been very marked general symptoms analogous to those of grave typhoid fever, which were followed by one or more abscesses beneath the integument from which had disappeared the erysipelas, and this last occurrence immediately resulted in amelioration, and convalescence was not slow to replace the grave state which had existed. It would, therefore, appear that, although this form of erysipelas frequently terminates in death, it is not proper to despair too soon. The same author reports the recovery of several cases of this disease, although they did not have abscesses. This is another resemblance to typhoid fever in which recovery sometimes takes place after the patient's life had been hanging in the balance as it were a certain number of days.

Erysipelas complicated with Pleurisy.—This complication is probably of infrequent occurrence. It is, however, occasionally observed even in very mild cases, and that, too, without a repetition of the initial chill. This complication is ushered in with pain in the side, dyspnœa, cough, and there may be soon observed the physical symptoms of pleurisy with effusion.

Gosselin reported a case which he had operated on for the purpose of establishing an artificial anus, at L'Hôpital Cochin, which was promptly followed by double pleurisy and effusion, and which speedily terminated in death. In some cases the pleurisy remains undiagnosed, and is only discovered at the autopsy, after the fatal occurrence. When the pleurisy is unilateral and without suppuration, it exercises very little influence on the progress of the erysipelas, and does not prevent recovery. But when it is developed in the course of a febrile disease, it is very probably due to a septic influence, and is very likely to end in suppuration which will necessarily render the prognosis much more grave.

Erysipelas complicated with Arthritis.—The arthritis like pleurisy is a rare complication, and it has been said of both, that they

are mere coincidences, and that no etiological relations exists between them and erysipelas. Gosselin does not endorse this opinion, because in the cases which he has observed, he has been unable to attribute these complications to either cold or any general cause, inasmuch as the serous and synovial membranes are sometimes involved in infectious diseases in the practice of surgeons and midwives, and since it is known that putrid poisons which cause fever and alter the whole organism, may produce, in certain subjects, more or less irritation in the membrane which I have already mentioned. However, inflammation may occur, as a complication of erysipelas, with a serous effusion into the large joints, and its influence on the progress of the primary disease will be about the same as in cases of pleuritic complications. If it does not suppurate, it acts the same as any other non-suppurating arthritis of infectious origin, like that of the puerperal state for example, and it may terminate in resolution with a restoration of motion, or in an incomplete anchylosis, while the erysipelas goes forward to a complete recovery. If, on the contrary, the suppuration should occur during the progress of the erysipelas, it should then be regarded as a serious complication.

Erysipelas complicated with Pyæmia.—L. Gosselin has observed in cases of erysipelas in which recurrent chills occurred between the eighth and tenth days of the illness, and where the patients became rapidly worse, the disease soon terminated fatally. The autopsy in each of these cases revealed metastatic abscesses in the lungs and liver, which removed all doubt in regard to the character of the complication.

TREATMENT.—The treatment of erysipelas, when it arises from a recognized solution of continuity involving the integument, should be primarily considered under two heads, viz., the prophylactic and curative, while the latter ought to be subdivided for study into constitutional and local.

Prophylaxis.—The value of the aseptic treatment of wounds, *even* as a prophylaxis against erysipelas, has been fully established during the last fifteen years. In fact, so much has already been written and said on this subject, that it seems scarcely

necessary to add another word; but, nevertheless, for the benefit of those who *are not so much prejudiced as to be entirely unwilling to examine any evidence in favor of this topic,* I shall venture to call their attention to the following statements made by Dr. Watson Cheyne: "I have brought forward a mass of evidence to show *what are the results of the various methods in avoiding infective disease,* and I must now refer to this evidence very shortly. We have seen that the aseptic method, when efficiently carried out, has practically abolished infective diseases, and that this result has been obtained whether the hospital was one in which these diseases were only present in small amount, as in Edinburgh, or whether it was one in which, from some cause or other, they were rife; where the hospital was, as it is said, infected. We have also seen that none of the other forms of antiseptic surgery gives the same *certainty* as regards the result, and that the absence of infective diseases increases in direct proportion to the increase in asepticity of the wounds. . . And so it may be truly stated that in *no case in which the aseptic method was efficiently carried out,* i. e., *where fermentation and micro-organisms were absent from the wound, did the patients suffer from blood-poisoning. In other words, the aseptic method, when efficiently carried out, was, in Mr. Lister's practice, effectual in entirely preventing infective diseases.* Similar evidence is furnished by Volkmann, Nussbaum, and others to the effect that in the very few cases in which the infective diseases occurred, faulty manipulation could be shown, and this is further proved by the facts that these cases occurred at the commencement of the trial of aseptic treatment, while as yet the surgeons were learning the method, and that as they have become thoroughly versed in its use, these diseases have disappeared."[1]

It has been absolutely demonstrated, I think, that it is quite possible to avoid the appearance of any septic wound complication in every case when the lesion is so situated as to enable the surgeon to properly apply the aseptic treatment; however it has been generally admitted that it requires the exercise of

[1] Antiseptic Surgery, p. 540 *et seq.*, London, 1882.

more skill to avoid the development of erysipelas in connection with wounds, than either septicæmia or pyæmia. It should be further observed in this conection, that, in order to employ successfully the aseptic wound-treatment as a certain prophylaxis against erysipelas, the dressing should be applied before decomposition has taken place in the wound secretion, or, more especially, before the organisms have found their way into the lymphatic vessels or the adjacent tissue. The importance of an early application of the aseptic treatment in these cases *should be strongly insisted on*, since the changes in the wound secretion and the lapse of time may render the most thorough cleansing of the wound and its surrounding parts, together with the most skilful application of the dressing, either completely or partially worthless. It therefore follows that this prophylactic treatment is best adapted to those cases of surgical operations involving a solution of continuity of the integument or recent wounds; but it may be unquestionably advantageously applied to others; since surgeons can never be absolutely assured that the contamination of the surrounding parts, which has already taken place, will ultimately produce erysipelas, prior to the appearance of this disease. Inasmuch as all the details of the antiseptic treatment of wounds have been fully described in another portion of this work, it is not deemed necessary to renew that description here, but it is undoubtedly proper to urge that every wound-dressing should be made strictly in accordance with the aseptic principles, in order to secure its full advantages as a prophylactic measure against erysipelas.

Curative Treatment.—A large number of remedial agents have been employed constitutionally and locally in the treatment of erysipelas. Among the constitutional remedies so employed, may be mentioned general blood-letting, the application of leeches over the inflamed lymphatic glands; emetics, purgatives, sedatives, such as digitalis and opium; tonics, such as the sulphate of quinine, and tincture of iron; stimulants, such as brandy, wine, and ammonia. These remedial agents were recommended to enable the surgeon to meet some real or imagi-

nary indications of the disease, and their employment was supposed to be limited to certain varieties of this malady, or even to particular stages. The antiphlogistics were employed during the inflammatory stage of the disease, while the use of the stimulants and tonics was reserved for the stage of debility. The object sought to be accomplished by the antiphlogistic treatment was the arrest or shortening of this stage of the disease, while stimulants and tonics were employed with the intention of hastening the convalescence of the patient. It has recently been demonstrated to the satisfaction of the majority of our profession, that the *antiphlogistic treatment can neither arrest nor shorten the progress of erysipelas;* and, furthermore, it is generally admitted that inasmuch as it is impossible to remove the *materies morbi*, or even limit their dissemination through the body by either general or local blood-letting, it is therefore thought that the chief effect of this procedure will be to weaken and still further embarass the condition of the patient. We now desire to call attention to the opinion expressed by Prof. Erichsen on this subject, who says: "*The curative treatment* of erysipelas must always be conducted with reference to the low character of the local inflammation, its tendency to run into suppuration and gangrene, the asthenic type that the constitutional fever readily assumes, and the frequent complication of visceral inflammations of a congestive form. The apparent intensity of the local inflammation must not lead the surgeon into the fatal error of employing an overactive antiphlogistic treatment, more particularly if the disease be epidemic, when it always assumes a low type. It is especially important to look to the future, and to remember that if active depletory measures be employed early with a view of lessening the present disease, it will be at the risk of inducing more extensive sloughing, and perhaps of lowering the patient's powers to such a degree as to prevent his bearing up under the depressing influence of the ulterior consequences of the disease."[1] The

[1] Science and Art of Surgery, vol. i. p. 681 *et seq.*, American edition, from the seventh and enlarged English edition, Phila. 1878.

use of emetics is chiefly based on their supposed derivative action, while cathartics are employed for the purpose of emptying the alimentary canal, effecting a removal of any deleterious material which it may contain, calming the patient, and checking the further progress of the disease. It is unquestionably true that both these remedial agents may be sometimes advantageously employed in the treatment of erysipelas; although it is very doubtful if either possess the power to materially check the progress of the disease, but a free cathartic action very frequently makes the patient much more comfortable. The digitalis is only employed in this disease as an arterial sedative, while opium is used to relieve pain and secure sleep. The knowledge we now possess of the etiology of erysipelas *should prompt us to seek for curative treatment only in those medicines which are known to possess the power to destroy pathogenic micro-organisms; and may it not be reasonably anticipated that in the near future there will be found in the mercuric bichloride or some other germicide a reliable specific for the cure of this malady.* In support of this opinion we will cite Phillips, who says that "In many cases of phlegmonous erysipelas, especially when occurring in strumous subjects, I have found the internal administration of corrosive sublimate distinctly useful."[1] Dr. George M. Sternberg has carefully examined this subject in all its bearings, and we will therefore present here his views in his own words: "The value of this potent agent as a parasiticide for external use is well established. The question now under consideration is whether it is practicable to use it in sufficient quantity to take advantage of its germicide power for the purpose of destroying or restricting the development of internal parasites located in the blood or in the tissues, *e. g.*, the bacillus of tuberculosis (?), the bacillus of syphilis (?), etc. etc. The proportion in which this reagent prevents the development of the septic micrococcus is 0.0025 per cent. equal to one part in 40,000. It is probable that a proportion considerably below this may have some restraining influence, and perhaps some

[1] Materia Medica and Therapeutics, vol. ii. p. 217.

of the pathogenic organisms are more susceptible than this micrococcus to its action. But reasoning from the experimental data at hand, let us see if the required amount could be administered medicinally. Physiologists estimate the blood to constitute one-eighth of the weight of the body, which for a man weighing one hundred and sixty pounds would amount to twenty pounds. The quantity of mercuric bichloride required to prevent the development of the septic micrococcus in this amount of blood would be three and one-half grains. 'The dose of corrosive sublimate is from the twelfth to the quarter of a grain repeated three or four times a day.' (U. S. Dispensatory.) 'The smallest dose which is reported to have destroyed life is *three* grains. This was in the case of a child.' (Taylor's *Medical Jurisprudence*, p. 130.)

"Probably one grain per day is the maxmium quantity which could be administered medicinally for several days in succession and it is evident that the amount required to obtain the germicide action of the reagent upon parasitic micro-organisms in the blood or in the tissues could not be obtained by these doses, unless there is an accumulation in the system from incomplete elimination of the poison. That this is the case, has been demonstrated by experiment.

"'If treatment have been continued some time, mercury may be found in the urine for several days afterwards; thus, in the urine of two patients who took $\frac{1}{8}$ grain daily for ten or twelve days, the drug was found for four or five days after treatment had been omitted. . . . . Years after its prolonged administration unusual perspiration may develop dark mercurial stains on the linen . . . . I have myself seen five patients while under the influence of nitric acid, suffer from salivation and other physiological symptoms of mercury, and none of these had taken that drug for over eighteen months previously: I consider it clearly traceable to the mercury in the system and not to the acid." (Phillips's *Materia Medica and Therapeutics*, vol. ii. p. 191.) In view of these facts it is not difficult to believe that the bichloride may be introduced into the system in quantities sufficient to restrain the development of parasitic

micro-organisms, and we will have a satisfactory explanation of the *modus operandi* of this remedy in syphilis, if this is eventually demonstrated to be a 'germ' disease."[1]

The administration of drugs for the cure of erysipelas *has been very unsatisfactory in the past;* but we now look to the future in anticipation of better results. It is, however, anticipated that there may be found some difficulty in introducing into the system, without endangering the life of the patient, a sufficient quantity of those medicines, which are commonly designated as "germicides," to effect the destruction or arrest the development of the parasite, which is essential to the cure of the disease. It is, therefore, highly important in the management of these cases to obtain the highest germicidal action which may be possible under the circumstances from any given quantity of medicine. It therefore seems desirable that the entire quantity of medicine employed should be brought, by the hypodermic syringe, directly into contact with the organisms, instead of being introduced into the stomach and carried from thence to some distant part of the body where the disease may happen to be located. It should be noticed here, that the medicine, when thrown into the diseased parts with the hypodermic syringe, must necessarily come into contact with the organisms in a *much more concentrated form,* where it remains for a longer or shorter period, *than when it has been introduced into the system by the mouth.* In concluding our consideration of the constitutional treatment of erysipelas, we are compelled to admit that, although there are certain conditions in which we believe the sulphate of quinine, tincture of iron, brandy, wine, and ammonia may be advantageously employed in the management of this disease, they are, nevertheless, improperly regarded as curative agents.

Local Treatment.—The local treatment of erysipelas, with the exception of the phlegmonous and gangreous varieties, may be justly regarded as essentially palliative and not curative. The surgeon should therefore select these agents with more especial

[1] American Journal of the Medical Sciences, vol. lxxxv. p. 336 *et seq.*

reference to the relief which they may afford the patient, than to any supposed curative power. It is not the intention of the author to deny the possibility that a sufficient amount of the active principle of certain lotions may be absorbed, to retard more or less the development of the organisms on which the existence and spread of this disease depend; but it is believed that the same results may be accomplished more readily by the use of the hypodermic syringe. Prof. Velpeau has given us some very interesting details in regard to the use of external applications in cases of erysipelas which we will reproduce. "M. Velpeau states that his experience, to the present, extends only to *external* remedies. He has treated one thousand cases or about *sixty* per annum, at his hospital, of which he has taken minutes of only *four hundred*. Since that time he has drawn the line of distinction between erysipelas and other inflammations; twenty-five of these cases have been treated by *compression*. In these the erysipelas continued from six and eight to twenty days. The redness diminished under the bandage, but the itching continued, and also the pain on the points that were compressed. The inflammation continued to spread. If, says M. Velpeau, I once thought otherwise, it was because, like the rest of the world, I confounded *erysipelas proper* with diffuse phlegmon, angioleucitis, and phlebitis.

He made trial in *thirty-three* cases of the temporary *blister* on the centre, and to beyond or only on the margin of the diseased regions; but in no case was the disease shortened; and it can afford relief only in the phlegmonous form or in angioleucitis.

The *nitrate of silvre* (*azotate d'argent*), in its natural state and concentrated, and also in all its modes of application, gave no better results.

Twice only he used the *hot iron*, after the mode of M. Larrey.

In *two hundred* he used the *Neapolitan* ointment, and without effect. 'The mercurial ointment,' he says emphatically, 'neither cures nor arrests erysipelas.' It may shorten it perhaps, a day or two, or render it a little less painful, the only reason for which I still sometimes use it, and for which it would

be still in use, but for the repugnance patients have to it, the *danger of salivation*, and the soiling of the linen.

We find that *hogs' lard* (*axonge*) *in twenty-three* cases moderated the erysipelas, but did not abridge its duration, and was of less efficacy than the mercurial ointment.

The disease in *twelve cases was aggravated* by an ointment of four grammes (*seventy-two grains*) *of white precipitate* to thirty of lard.

Sulphuric acid in *ten cases*, applied as a lotion to the skin, had no sensible effect.

The *hydrochloric* (*chlorhydrique*) *acid* in ten cases was not more satisfactory.

The *citric and tartaric* acids, the *oxycrate* (vinegar and water) and *salt and water* (*eau salée*) or solution of *chloride* (*chlorure*) of *sodium*, were each employed in six separate cases without effect.

In six cases, the *nitrate acid of mercury*, in three as a lotion and in three as a caustic, proved useless.

Camphor and the *bird-peck punctures* (*mouchetures*) were equally unavailing.

Prof. Velpeau had in despair renounced all the above remedies, though practitioners still believe in the effcacy of the blister, nitrate of silver, mercurial ointment and lard, until his attention was drawn to the *changes effected upon the blood by the preparation of iron*."[1]

He then proceeds to make a trial of the sulphate of iron and concludes his remarks on the subject in the following language: "Unless, therefore, says M. Velpeau, numerous and remarkable coincidents have on this occasion deceived me, as so often happens to others, there is good reason to believe in the efficacy of sulphate of iron as a topical application in erysipelas. In *no* case did the inflamed surface resist this means over twenty-four to forty-eight hours. It is only strange that the spreading (*ambulant*) erysipelas, extinguished at the point of its origin, continued, nevertheless, under this treatment to develop itself, even upon the regions already covered and wet (*enduites et imbibées*) with

[1] New Elements of Operative Surgery, vol. i. p. 68 *et seq.*, Mott, N. Y., 1851.

the preparation of iron. Can it be that this remedy, like so many others, may be curative but not preventive? Is it necessary, in order that the inflammation should be modified, that it should be completely established?"[1] It is probable that there is no living surgeon, who has seen or treated so large a number of cases of erysipelas as Velpeau: and consequently the opinion which he has expressed in reference to the results of the local treatment of the disease, are entitled to careful consideration. It is true that we now employ a considerable number of topical applications which were not used by Prof. Velpeau, and it is also probable that we are enabled to make our patients more comfortable by their use, but there are *none of them, whose curative powers we can laud so highly as did Velpeau the sulphate of iron.* In concluding our remarks on this subject we shall briefly mention some of the topical applications, which are now frequently used, but which were not mentioned by Velpeau.

These remedial agents are commonly applied to the diseased surface in the form of lotions, oleates, or ointments, although poultices are not infrequently employed. The medicinal agents most frequently used are the following: acetate of lead, opium, morphine, perchloride of iron, oil of turpentine, tincture of iodine, iodoform, collodion, glycerine, carbolic acid, etc. The milder forms of cutaneous erysipelas are frequently greatly relieved by the external application of some vaseline, which abates the heat and burning, and the same class of cases are said to be made very comfortable by the employment of the cranberry poultice.

GANGRENE.

DEFINITION.—The term *gangrene* is now employed synonymously with *mortification* or *sphacelus*, and is applied to a condition in which there is an arrest of the functions of organic life in a circumscribed portion of the soft parts of the body, which sooner or later terminates in the complete death of the

[1] New Elements of Operative Surgery, vol. i. p. 71, Mott, N. Y. 1851.

same. This disease is primarily divided into traumatic and idiopathic—terms expressive of the different modes of origin—although some surgeons employ the terms *moist* or *dry* before the word gangrene to designate the pathological condition of the diseased parts. The idiopathic is essentially a dry form of gangrene, while the traumatic generally corresponds to the moist. In our consideration of gangrene, we have only to *deal with the traumatic form of the disease, since the idiopathic rarely exists in connection with wounds*, and its origin is never dependent upon them. It seems only proper to regard *hospital gangrene* as a subdivision of the traumatic form of the disease, since it never exists except in connection with a wound, and is undeniably a septic wound complication.

HISTORY.—The prehistoric man, like his brother of the present age, must necessarily have been exposed to accident and bodily injury in his struggles for an existence, and consequently *traumatic gangrene*, as the result of mechanical force and the local action of physical and chemical agents, must have made its first appearance soon after man. It might, therefore, be properly anticipated that the earliest medical authors would have something to say on this subject. In this anticipation we have not been disappointed, since Hippocrates mentions phagedenic spreading ulcers and describes gangrene. Pliny, in that portion of his "*Natural History*" which treats of medicinal remedies, has mentioned gangrene and other morbid conditions. Galen was regarded as a high authority on mortification by ancient authors, and has been extensively quoted by Oribusius, Ætius, Paulus, and others. Dr. Joseph Jones says, that "Mr. Blackadler, in his valuable 'Observations on *Phagedæna Gangranosa*,' has shown that several of the ancients in their descriptions of foul gangrenous ulcers must have alluded to the same kind of disease which is now denominated hospital gangrene; and that beside the use of actual cautery, several of the older writers, as Ætius, Paulus, Celsus, Rolandus, Avicenna, Guido, and others, employed, for the cure of such ulcers, arsenical preparations."[1]

[1] United States Sanitary Commission Memoirs, Surgical, vol. ii. p. 211.

Aretæus, the Cappadocean, makes *no mention of hospital gangrene*, although he alludes to gangrene following the introduction of the catheter into the bladder, and to the spreading phagadenic ulcers of dysentery. Paulus Ægineta wrote quite extensively on the subject of mortification, during the first half of the seventh century.

The works of Rogerus, Brunus, Theodocius, Lanfrancus, Bertapalia, and other authors of the thirteenth and fourteenth centuries contain descriptions of putrid and corrosive sores. There is an abundance of evidence to show that in the early part of the sixteenth century the extensive prevalence of gangrene led surgeons to suppose that gunshot wounds were poisoned. Dr. C. Thiersch says, that "in the beginning of the sixteenth century, Johannes de Vigo had only to put into a dogmatic form the already established view of the physicians of the time. A gunshot wound is a contused wound, he says, for the bullet is round; it is burnt, for the bullet is heated; it is poisoned, for powder is poisonous. This poisoning is the essential condition, therefore the treatment must be directed above all to counteract this."[1] Alphonsus Terrus published in 1534 one of the first treatises on gunshot wounds, and he declared that these wounds were poisoned with the gunpowder. Ambrose Paré seems to have been the first surgeon who comprehended this error. This distinguished surgeon participated in the siege of Rouen, about three hundred years ago, and there observed that "many wounds sloughed, and had a cadaverous smell, and on opening the bodies of those who died, numerous collections of pus were found in various parts of the body full of greenish, ill-smelling ichor."[2] Beseigers and beseiged believed themselves to be wounded with poisoned bullets. Paré looked for the cause in a deterioration of the air by the large quantity of decomposing substances. There *can be no doubt* in the minds of those who are familiar with the atmospheric conditions which *invariably produce septic diseases*, that both hospital gan-

[1] German Clinical Lectures, p. 67, New Sydenham Society, 1877.
[2] Ibid. p. 67 *et seq.*

grene and pyæmia were prevalent during the seige of Rouen, among the wounded of that unfortunate city. This opinion is further confirmed by the description of the wounds which has been handed down to us, and the pathological lesions which were revealed by the *post-mortem examinations*. Richard Wiseman's *Surgery*, which was published in 1676, contains a chapter which is devoted to the consideration of Gangrene and Sphacelus, in which he describes these morbid conditions as follows: "The most cruell symptoms that attend Gun-shot and great contused Wounds are *Gangrena* and *Sphacelus*. *Gangrene* is a tendency to Mortification: it invades the softer parts, as the Skin, Flesh, etc., and is the beginning of a *Sphacelus*. *Sphacelus* is a perfect Mortification with the extinction of the native Heat and privation of Sense, not only in the Skin, Flesh, Nerve, Artery, but the very Bones. They differ from one another as the Mortification is more or less."[1]

An examination of this chapter shows that this celebrated English author was fully acquainted with both the idiopathic and traumatic forms of this disease; but that *he did not recognize the agencies which are especially active in the production of hospital gangrene*. The pernicious effects of an atmosphere loaded with the products of decomposed animal and vegetable matter, on wounded patients, are not even remotely hinted at by him. It, therefore, appears that the opinions of Ambrose Paré had not been generally accepted by surgeons; although his treatise on gunshot wounds first appeared in Paris, in 1551; and his complete works were published at Lyons, in 1562.

It is also undeniable, that notwithstanding the fact, that surgeons had been more or less familiar with both forms of gangrene, even from prehistoric times, and, furthermore, military surgeons had frequently seen epidemics of hospital gangrene, which had carried away thousands of wounded soldiers, and *still this latter variety, a most formidable enemy of mankind, remained almost unknown until the latter part of the eighteenth century*. It is true, Paré recognized some of the active agencies

[1] Wiseman's Surgery, p. 443.

in its production; but neither his discovery nor his writings produced any favorable results which are now perceptible in the literature of this subject.

Pouteau has given the first good description of hospital gangrene, in a paragraph of his excellent work, which was published in 1783. He expresses surprise that the writings of Quesnay, which appeared in 1749, contained nothing relating to this subject. He says that hospital gangrene is a disease which had not previously engaged the pen of any author. Nevertheless he speaks of it as a well-known disease, a very dangerous complication of all open wounds treated in overcrowded rooms, designated by the name, "moist gangrene of hospitals," and a malady which takes its origin from the bad air surrounding the patient. De la Motte gives us in his *Complete Treatise on Surgery*, which was published in 1722, the key to the solution of these riddles. He mentions at the commencement of his chapter on mortification, hospital gangrene, as "*Gangrene im engerro sinne*," and refers to the same wound complications, which at that time were designated at the Hôtel Dieu, in Paris, as "*Pourriture*." He adds that this form of gangrene occurs in all the wounds and open abscesses which are placed in the crowded wards of hospitals; and is there designated, "*Pourriture*," in order not to injure the patients who would be greatly alarmed if the disease were called by its right name. It was admitted after this declaration, that *hospital gangrene* had then been long indigenous in the Hôtel Dieu, and was there regarded as a *much dreaded guest*. These statements are confirmed by Foudéré, who informs us that the prevalence of hospital gangrene in the overcrowded wards of hospitals was a common occurrence toward the end of the sixteenth century. There is no reason to believe that an infectious germ disease, like hospital gangrene, should fail for centuries to make its appearance even under the most favorable circumstances, especially as the *contagium vivum* is so light as to be floated on every breeze. It is, therefore, more than probable, that the non-appearance of any discourse on the subject of hospital gangrene, in the early medical literature, is due to a desire for its concealment, a faulty

diagnosis, a failure to appreciate the important pathological changes which occur during the different stages of the malady, or the multiplicity of names by which it has been supposed to have been designated. It is evident that many of the ancient surgeons were not accustomed to carefully study the external appearances of local affections, especially the various characteristics of wounds; but that their attention, on the contrary, was fixed on the constitutional manifestations, *particularly the fever, which they seemed to believe* constituted the essential part of all maladies. We, therefore, find the following terms are frequently employed in the medical literature in place of hospital gangrene; thus Larry substitutes, *fièvre noso-comial*, while others employ *wound typhus, typhus putridus, typhus traumatique, wound cholera, hospital fever*, etc.

Dr. Ollivier in 1822 first expressed the opinion that *hospital gangrene is diphtheria* engrafted on an open wound. M. Robert reiterated this opinion in 1860, and classified the disease as follows, according to its different degrees of intensity: 1. *Diphtheria simplex;* 2. *Diphtheria pulposa oder gangrænosa;* 3. *Diphtheria ulcerosa.* He declares that the first variety of this disease commonly arises from the contamination of the atmosphere in the over-crowded wards of hospitals, and is *very rarely* contagious, while the other and severer forms of the disease may be produced by the same causes, but they *are contagious.* Many distinguished German surgeons have recently expressed opinions similar to those just recorded, and among them may be mentioned V. Pitha, Virchow, Billroth, Hueter, and H. Fischer.

Having presented some of the outlines in the history of traumatic gangrene, we are now prepared to enter on the consideration of its causes.

Etiology.—Gangrene may be produced by either local or constitutional causes, but in some instances it is the result of the combined action of both of these agents. The constitutional causes are the chief factors in the production of *dry gangrene*, although local injuries are often contributory agents in this form of disease. *Traumatic gangrene, on the contrary, always takes its origin from local injuries, and constitutional causes only act as predisposing agents.* It should be remembered

that the traumatism in the traumatic form of the disease is a very essential factor in the gangrene. It is not only *the predisposing cause* in the majority of cases, but *the pathological changes are also chiefly determined by it.* In former times, when the process of putrefaction *was not so well understood* as at the present, surgeons were greatly embarrassed in their attempts to explain the difference between *dry* and *moist* gangrene. We now easily comprehend, that the essential difference between *moist* and *dry* gangrene arises from the fact, that in the former instance the death of the parts is followed by the ordinary putrefactive changes, while in the latter case the soft parts merely dry up. In order to understand this subject *more fully, it is only necessary* that the student should make himself thoroughly acquainted with the modern theory of putrefactive fermentation. Prof. Billroth has called our attention to the fact, that "moist gangrene, from the very moment when the circulation ceases, becomes a process which is entirely analogous with the process of ordinary putrefaction;"[1] and he also adds, that "dry gangrene, the mummy-like drying up and shrinking of the parts, is more frequently the result of a gradual death, during which the circulation in the deeper parts, though becoming weaker and weaker, still goes on for awhile; the serum of the gradually necrosing tissues is taken up and carried away by the lymph-vessels and veins. The rapid evaporation of the fluids from without also helps to bring about a gradual drying up of the necrosed parts."[2]

The true explanation of the non-appearance of putrefaction, in cases of dry gangrene, is unquestionably due to the activity of the agencies which have just been mentioned in preventing the exposure of a sufficient quantity of albuminoid fluid to serve as a nidus for the multiplication of the germs, and consequently it will be observed that this process is somewhat analogous to that by which the skins and flesh of animals are frequently preserved, which merely consists in the liquefaction and evaporation of the fluids within the parts. The immediate cause of gangrene in any part of the body is generally the result of the

[1] Surgery, vol. i. p. 423, London, New Sydenham Society, 1877.
[2] Ibid. p. 424.

complete arrest of the supply of the nutritious fluids, in consequence of the suspended circulation in the capillaries; but this condition may be produced by various physiological, pathological, mechanical, or chemical agencies. The etiology of gangrene, as a wound complication, presents itself for examination in two forms; the one a *septic* and the other a *non-septic* disease. The *septic variety* takes its origin from the introduction of septic poison into a wound, as in the case of hospital gangrene, the bite of *certain venomous serpents, etc.*, where it sooner or later produces the death of more or less of the surrounding soft parts.

The *non-septic variety* of *traumatic gangrene* may have its origin from *mechanical violence*, such as might result from the passage of a cart wheel over a limb, crushing and disintegrating the tissues. The same form of gangrene may arise from *mechanical pressure*, such as too tight application of a bandage to an extremity, the strangulation of a limb by a tourniquet, or the production of gangrenous sloughs on the lower portion of the back, or the outer part of the hips, by prolonged decubitus. It may be justly observed here, that the *mechanical pressure*, in the case of bed-sores, is only one of the combined agencies which are more or less active in the production of this annoying complication. This form of gangrene may appear in connection with any disease of the brain, spinal cord, or their membranes, which results in paralysis, and thereby necessitates the maintenance of decubitus. It may likewise arise in cases of peritonitis, typhoid fever, or other diseases which are attended with great prostration and loss of consciousness, to such an extent as to cause the patient to disregard personal cleanliness. In all these cases, the *blood changes, anœmia, etc., and also the excretions which soil and irritate the parts* are unquestionably active agents in the production of bed-sores.

Having called attention to the effects of mechanical violence and pressure in the production of gangrene, we will now pass to the consideration of chemical agents in the same role. These agents are equally as powerful and more prompt in the production of gangrene, than those which have been already mentioned, and they include the corrosive acids and alkalies, heat,

cold, etc. This action has been well described by Prof. S. D. Gross, who says: "The influence of chemical agents in producing inflammation and mortification is exemplified in various ways. The contact of the alkalies and acids, if very slight, will, in general, cause merely a rubefacient effect; if more severe, it will induce vesications; while, in its worst form, it occasions instantaneous destruction of the tissues. The application of heat and cold acts very much in the same manner. In all these cases life is destroyed, either by the primary impression of the chemical agent, or as a consequence of the violence of the resulting inflammation." In persons of feeble organisms, especially in young children impoverished by starvation and disease, the application of a common blister is often followed by extensive sloughing; and a similar effect is occasionally witnessed as a result simply of the protracted use of a mustard plaster. There is abundance of evidence to show that every variety of traumatic gangrene may arise apparently from an insignificant exciting cause; but it is commonly quite evident that in all these cases, there is at work a strongly *predisposing agency*."[1]

Dr. Ernest Wagner says on this subject, "All parts are, in general, *predisposed to gangrene*, in which there exists a disturbance of the circulation of any kind (anæmia, hyperæmia, thrombosis, hemorrhage, or œdema); but these disturbances produce gangrene only in their highest grades. Inflammation in all its effects, especially parenchymatous exudation and purulent infiltration, likewise disposes to gangrene. In a similar manner, probably, a faulty blood-mixture, as in inanition and diabetes, in drinkers, perhaps also in various forms of acute and chronic forms of marasmus, caused by hunger as well as disease (typhoid fever, etc.), leads to gangrene. . . . . The same disposition to gangrene is found in parts of the body after interruption of nervous activity, nutrition, etc., *e. g.*, in injury of the sensory nerves, especially of the fifth (peculiar corneal softening), in parts paralyzed as to motion, in both cases less, because

[1] System of Surgery, vol. i. p. 159, fourth ed., Phila. 1866.

insensible or immovable parts can sufficiently escape injurious external influences (in paralysis, moreover because the support to the venous blood-circulation is destroyed), than on account of the simultaneous paralysis of the vaso-motor nerves. Also dropsical parts (extremities, scrotum, external female genitals, so-called white gangrene) are disposed to gangrene, and to a less degree frozen extremities."[1]

Having briefly considered the most active causes in the production of the *non-septic variety of traumatic gangrene*, we now turn to the study of the etiology of the septic form of the disease. There is included in this variety, *hospital gangrene* and *every other form of mortification*, in which a septic poison acts as the exciting cause. The causes of hospital gangrene may be classified as predisposing and exciting. The active predisposing causes may be briefly stated to consist in a disregard of hygienic laws: although there are cases in which constitutional diseases and vicious habits render patients more liable than they would be otherwise to contract this malady. The question may be properly raised here, what is the relation of an open wound to hospital gangrene? It is generally admitted that a solution of continuity in the soft tissues is the *sine qua non* for the development of this disease. It has been satisfactorily demonstrated in the practice of antiseptic surgery, that the *contagium vivum* must be received on the unhealed surface of an open wound, in order to become effective. The conditions required in this respect are similar to those known to be necessary for the production of the vaccine disease. The contagion cannot penetrate the skin or mucous membrane, but a mere scratch or abrasion of the same is all that is required to render it operative. The attention of the medical profession has been called to a curious fact recorded in the *Medical and Surgical History of the War of the Rebellion*, where it is stated that: "A peculiar feature in the above table is the fact that with the exception of the penetrating wounds of the trunk, the percentage

[1] A Manual of General Pathology, translated from the sixth German edition by Dr. J. Van Duyn, p. 338.

of fatality of the cases of gangrene after flesh wounds is larger than that after fractures. The death-rate of the cases of flesh wounds of the head, face, and neck, complicated by gangrene is 58.3 per cent., while that of the fractures is only 33.3 per cent. Likewise the death-rate of flesh wounds of the upper extremities attacked with gangrene is 51.5 per cent., while that of fractures complicated with gangrene is only 33.9 per cent.

"In the lower extremities the mortality after gangrenous flesh wounds is 50.3 per cent., while that of the fractures is 48.7 per cent. In the wounds of the trunk alone the mortality of the fractures and penetrations exceeds that of the flesh wounds, the former being 68.7, the latter 47.0 per cent. Of the two thousand three hundred and sixty-six instances of gangrene in the extremities, one hundred and eighty-five were cases of gangrene following excisions, and in forty-six of these cases amputation of the limb had to be resorted to. The great liability of excisions to this complication will be referred to hereafter. In eight hundred and ninety-eight instances gangrene was noted on the face of the stump. In a few of these cases the complication was caused by strangulation of the stump by tourniquet. In the following instance the gangrenous condition of the limb was ascribed to the tight application of bandages. . . . But the large majority of the cases were instances of hospital gangrene caused by the crowded condition of the hospitals, and the bringing together of many cases of extensive fractures and large operation wounds."[1]

We are now in possession of sufficient facts, bearing on this subject, to justify the conclusion that large open wounds are no more liable to be attacked by gangrene than smaller ones, and that the complication of a wound by a fracture, *does not increase the danger from the gangrenous complication*. Another *important relation* of open wounds to *hospital gangrene*, is shown by the fact that this disease cannot originate *de novo* except in the presence of a suppurating wound, and surrounded by the putrefaction of animal matters. In the month of April, 1863, hospi-

[1] Part Third, Surgical Vol., p. 824.

tal gangrene first made its appearance in the military hospital at Nashville, Tenn., and Surgeon M. Goldsmith, U. S. V., was sent there to examine into its origin.

The facts *elicited by this examination show that the disease had an indigenous origin*, while the report is *highly instructive and bears most forcibly on the subject now* under consideration. He says: "1. All the cases occurred in ward No. 1. 2. All cases occurred in the row of beds next the windows opening upon an alley. 3. All cases occurred prior to the twenty-fourth of April, or during the time when the external atmosphere was colder than that of occupied houses, inclosed cellars, or underground drains. 4. The cellar under the hospital had passing under and opening into it, by several apertures, the common sewer of that part of the city. 5. The soil pipes from the privies of the several wards traversed the cellar and emptied, without a trap, into the common sewer. 6. This soil pipe was made of tin and leaked badly. 7. In wet weather the cellar bottom was overflowed by the contents of the soil pipes and sewer. 8. This cellar had but two openings, one in front of the building and one on the alley. 9. The alley was long, narrow, and high (five stories). 10. The area of the adjacent building received the drainage of the garbage of the kitchen, and this area formed a part of the alley. 11. Ward No. 1 derived its ventilation almost entirely from windows opening on the alley. On the opposite side there was but one opening, a door leading to a hall which had no window. On the end next to the street there were but three windows. 12. The prevailing winds during the cold weather sweep the street on the front of the building, leaving the atmosphere in the alley almost still. 13. The emanations from the area of the adjoining building, as well as those from the cellar, were most offensive at all times, and were disgustingly perceptible in the evening when the external atmosphere began to cool. 14. No cases of hospital gangrene occurred after the weather grew so warm that the outer air was warmer than the air in the cellar sewer (after April 24). 15. The building on the opposite side of the street (the alley running through only one square) prevented any wind from sweeping it, below the

second story. . . . It will appear from the fact related that the miasm generated by putrefying animal matters in the cellar, and perhaps in the area, are given off at such seasons, and that just during that season when, from the relations of temperature, the atmosphere of the cellar would ascend in the alley and the currents would enter the wards most constantly, *i. e.*, when it was necessary to heat the wards with stoves, the cases of gangrene occurred; and they occurred in just that locality in which the gases would impinge upon the patients in most concentration; and that when the miasm of the cellar would flow downward, *i. e.*, when the external air was warmer than the air in the cellar, and when from the extinction of fires no air was drawn in at the windows, the disease ceased. The testimony of the surgeon having the ward and cases in charge is all the more valuable that he did not anticipate or interpret the facts. He noticed, without peculiar interest, the occurrence, and, as he expressed himself to me, supposed that by some singular accident the patients having the 'lowest vitality' were placed in that row of beds: and he marvelled greatly that the cases should occur when the ventilation was best, because the windows in the alley were the only available outlets for air in the whole ward, and were opened fully and diligently four times a day in even the coldest weather, and some part of the windows were kept open all the while. I think that the records of surgery do not afford a more unique or striking example of one of the methods of the production of hospital gangrene, or afford a more pertinent commentary on the use of buildings constructed in utter disregard of all hygienic rules."[1]

Dr. Goldsmith has merely repeated the old story, which has been so frequently told us by other authors with all the details, including the unsavory and unhygienic conditions in which hospital gangrene originates. It is true, there is some slight variation in the narrative, as told by different authors—in one instance the poison is generated within the hospital ward by overcrowding with patients suffering from suppurating wounds,

[1] Medical and Surgical History of the War of the Rebellion, Part Third, Surgical Vol., p. 832 *et seq.*

defective ventilation, disregard of cleanliness, etc., while in other cases it may come from without, but the *essential condition must always exist in order to produce the disease, viz., the vitiated impure air, loaded with the products of decomposing animal matter must surround the victim of an open wound. Whenever it is possible to avoid this condition, hospital gangrene will fail to make its appearance—will cease to exist.*

It is a fact so well established and so generally admitted by all authorities on this subject, that hospital gangrene having once gained a foothold, may then spread by virtue of its own contagious property, so as to render it almost unnecessary to call attention to anything bearing on these points. This contagion is commonly carried from the infected patient to those whose wounds are not thus diseased by the dresser's hand or instruments. The sponges, basins, forceps, scissors, and bandages frequently convey the poison from one patient to another. The hands of the dresser are probably even more dangerous than any of the instruments employed in dressing wounds, with the exception of the sponge. The little cavities about the finger nails serve as depositories in which the poison may be stored up, and where it may remain in spite of the ordinary methods employed for cleansing the hands, until the dresser again finds it necessary to insert his fingers into a non-gangrenous wound, which would thus be exposed. Another source of danger is found in the furniture of the ward and hospital, including the bedding, etc. It was formerly denied by some excellent authorities that hospital gangrene could be transmitted through the air. We are informed by Dr. John Hennen that Mr. Blackadder "considers the hospital gangrene as a local disease, and not communicable by the atmosphere, but solely by inoculation. No man can doubt that it is very frequently communicated in the latter way, but if what I have already stated, from my own knowledge of the disease at Bilboa, is insufficient to show that it is also communicable by atmospheric influence, the following facts from the paper of Professor Brugman's, to which I have already referred, will, I think, prove it very clearly. 'At Leyden, in the end of the summer of 1798, in the French

military hospitals, hospital gangrene prevailed in one of the low wards, whilst the patients who had slight wounds, and who were placed above this ward, in a well-aired garret, were found to escape the disease. The surgeon judged it necessary to make an opening in the floor, in order by that means to afford an outlet to the air of the infected ward by the roof. Thirty hours afterwards, three patients, who lay near to the opening, were attacked by the disease, which soon spread through the whole ward. In the preceding cases, the contagion was diffused in the atmosphere, and the miasm to all appearance applied directly to the surface of the ulcers.' "[1]

The origin and spread of hospital gangrene certainly resembles that of pyæmia and diphtheria. Spontaneous outbreaks of these diseases may occur at any time when the surroundings are favorable. They develop very rapidly under the influence of poisonous miasms, especially in the presence of the foul gases and other débris arising from the decomposition of animal substances; and it is therefore probable that, during some stage of the putrefactive process, there are developed germs, which are capable of producing these morbid affections. These germs having fallen on a fertile soil are reproduced *ad infinitum*, and consequently, each patient suffering with hospital gangrene, or any other similarly contagious disease, becomes the centre for the dissemination of the *contagium vivum*. It therefore follows that the greater the number of gangrenous cases, confined within a given space, while the external conditions, ventilation, etc., remain unchanged, the greater must be the danger from the contagion. Dr. C. Heine has recently prepared and published in the German language, a most excellent article on the subject of hospital gangrene, in which he presents the experiments and opinions of a host of investigators bearing on the etiology of this disease; but he finally concludes after all which has been said on this subject, that it originates in a local infection of a wound with *a specific materies morbi—the diphtheria poison—which is contained in the secretion of diseased wounds, is*

[1] Principles of Military Surgery, Phila., 1830, p. 194 *et seq.*

taken up by the air and may be carried to other patients; and that this disease terminates, only under peculiar circumstances, in a general infection of the blood from the local nidus, which is to be regarded merely as a septic complication. The authorities on hospital gangrene are now generally in accord with the views expressed by Dr. Heine in regard to the local character of the affection and its occasional complication by pyæmia. The German authorities fully agree with the opinion which he has expressed in regard to the nature of the poison by which it is produced. They assert that wound diphtheria, differs in none of its essential points from the other forms of this disease. There are many questions which might be more fully discussed in connection with our consideration of the etiology of hospital gangrene; but it is thought that the nature and causes of the disease are now *so well understood by the profession* as to render further comments on the subject by us unnecessary, and for a similar reason we shall not dwell at much length on the other forms of septic gangrene. The mystery which so long surrounded the action of decomposing animal substance, when kept in contact with wounds, *has been recently explained.* The traumatic inflammation which was formerly supposed to be inseparable from an incised wound is now known to have its origin in the putrefactive process.

Septic inflammation and septic gangrene are unquestionably very frequently allied conditions. In the various forms of septic gangrene the inflammation generally accompanies the disease, and in those cases in which the septic material (animal poison) has been thrown directly into the living tissues, as in the cases of urinary infiltration or the bites of poisonous snakes, the inflammatory process precedes the gangrenous attack. There is still much to be learned in regard to the nature and action of this septic material. The researches which have been made during the past, have brought us to that position where we are enabled to assert with confidence, that the deleterious agent arising from the decomposition of animal matter is a *contagium vivum*, and *not a chemical poison* as was previously supposed, but it has not yet been clearly shown why a patient in one

instance should merely *suffer from septic inflammation*, and in another case from septic inflammation and gangrene. The views which were held in 1866 in regard to some of the varieties of septic gangrene and the agencies by which they were produced, were thus tersely and briefly stated by Prof. S. D. Gross, who remarked that "The infiltration of urine in the cellular tissue of the perineum often produces wide-spread gangrene of the scrotum; and portions of peritoneum sometimes perish from the contact of bile and feces. Although nothing of a definite character is known of the nature of animal poisons, yet it is highly probable that they induce inflammation and gangrene very much in the same way as the acids and alkalies. Some of these poisons are the product of a peculiar secretion with which the animal is provided, as a means of defence; others, on the contrary, appear to be developed in consequence of a peculiar septic action, which is particularly strong during the last moments of life, and for a short time afterwards, before the tissues have undergone much decomposition. However generated, their insertion into the living structures usually awakens a peculiar form of inflammation, which not unfrequently terminates in the death of the affected structures; often with extreme rapidity, as, for instance, in snake-bite, chancre, and malignant pustule."[1]

It must still be admitted "nothing of a definite character is known of the nature" of the secretions with which certain animals and reptiles are provided as a means of self-defence, beyond the simple fact that their bites are followed by about the same symptoms as arise in cases of septic poisoning, and consequently in our consideration of this subject, we have placed them in the same classification.

PATHOLOGY.—The pathological changes in all the varieties of uncomplicated traumatic gangrene are essentially those of putrefaction in the soft tissues. These changes are not always uniform, and will necessarily depend, in some degree, on the composition of the dead parts, especially the amount of blood

[1] System of Surgery, fourth edition, vol. i. p. 159.

and water contained in the same. Gangrene is easily recognized by the fact that the dead part promptly loses its elasticity, its *turgor vitalis*, and becomes withered, soft, and doughy, while at the same time, in all cases of moist gangrene, the odor of putrefaction soon becomes marked. It is now universally admitted that putrefaction is caused by the growth and multiplication of certain micro-organisms, and that this process is somewhat analogous to that of saccharine fermentation. These organisms are readily destroyed by boiling or freezing, and their activity diminishes as the temperature approximates either of these extremes.

The micro-organisms by which the decomposition of albuminoid substances is accomplished, are apparently unable to penetrate even the soft tissues of the body; but, however this may be, it has been *fully demonstrated* that they never cause putrefaction except in the presence of moisture and oxygen. The soft parts of the human body are supposed to contain, in their normal state, about 81 per cent. of water, and this quantity is increased by the process of decompositon; thus affording an abundance of this fluid for the solution of all the tissues except the bony. Observation has shown us, that in all cases of moist gangrene, the bloodvessels are over-distended prior to, and at the time of the death of the soft parts, thus increasing the quantity of water, which evaporates *very slowly, owing to the presence of the epidermis*, so long as it covers the dead tissues.

This accumulation of blood in the diseased parts in cases of moist gangrene, is due to an obstruction in the veins and the venous capillaries, while the interference with the circulation in all cases of dry gangrene occurs in the arteries. It should therefore be observed, that in moist gangrene, the arteries carry the usual amount of blood to the diseased parts, and the obstruction in the veins prevents its return; but in cases of dry gangrene, the arterial supply to the affected parts is gradually cut off, and the veins, being unobstructed, convey away the blood and leave the dead parts dry.

Decomposition of the blood in the parts occurs soon after the death of the tissues, and the coloring matter leaves the blood-

corpuscles, coloring first the serum, and afterwards those tissues which are normally colorless or nearly so. The walls of the vessels and the loose cellular tissue around them become colored, so that the course of the veins may be recognized by bluish-red stripes, which, when the gangrene affects the external parts, gives the skin a blue, marbled appearance. In due time all the parts become uniformly stained with this coloring matter; even the adipose tissues form no exception. The colored serum extends to the surface of the cutis in the external parts. The decomposition going on in the various parts of the integument favors a loosening of the impervious epidermis, and the accumulation of serum beneath it. These changes give rise to the formation of bullæ or even larger accumulations of serum, conditions which may soon be followed by the detachment of the epidermis in the larger patches. The removal of the epidermis is followed by a rapid evaporation of the water, and likewise a desiccation of the superficial parts exposed to the air. Prior to the commencement of the desiccative process the soft tissues are thoroughly saturated with serum, containing the coloring matter of the blood; and consequently when dried they assume a very dark or almost black color. This process of decomposition goes forward in the blood more rapidly than in any of the other animal substances. "The colorless protoplasm dissolves under moderate intumescence and disappears from view. There is soon no longer a single intact blood-corpuscle to be found. The changes of the nucleated cells form the second group of necrotic phenomena. We may here state the proposition at the commencement, that the nucleated clump of protoplasm, as soon as life is really extinct in it, comparatively soon undergoes solution. The disintegration is introduced, and in a certain degree prepared by a phenomenon, which in striated muscular fibre has for a long time been designated as *rigor mortis*, and which essentially depends upon the coagulation of that viscid albuminate in which all the formed constituents of the cell, including the nucleus and the protoplasm, are imbedded. The protoplasm becomes immovable by coagulating, and indeed in a position corresponding to that of the cell in repose; the

granules also, which previously showed perhaps some molecular motion, now stand still; the entire appearance becomes cloudy as if dusty, and finally breaks up into relatively large granules, which then become smaller and disappear from view. The nucleus, which at first stood out prominently, likewise takes part in this disintegration."[1] "In gross the external parts in moist gangrene appear at first looser, more flaccid, doughy, discolored; sometimes the coloring matter of the blood settles and there appears a dark, bluish, or dark red coloring. The epidermis, or the whole epithelial layer, is raised in blisters, which are filled with a reddish or brownish fluid (so-called gangrene vesicles); beneath them especially putrefaction goes on. The parts break up with great stench, at first into ragged, withered, then greasy and liquid masses of blackish, brownish, yellow appearance. Some portions dry up, others fall off or remain attached to tendons, ligaments, bones. In gangrene of whole extremities, destruction of the skin and connective tissue for the most part progresses further than that of the muscles, and the latter further than that of the bones. The sulphuretted hydrogen generated, colors silver probes and lead ligatures black through the formation of the sulphide of silver and the sulphide of lead. . . . . Under the microscope the tissues in moist gangrene appear at first only clouded, retain their form, but later break up always into small colorless particles, so-called granular detritus. At first the blood-corpuscles and fat-cells are destroyed: fat is found mostly in very great quantity, mostly free, partly in crystals. The former depend for the most part upon the destruction of tissues, in part perhaps also upon an infiltration from without. The so-called gangrenous ichor consists chiefly of water, decomposed blood and fat, and molecular masses. Gland-cells and epithelium are destroyed almost as quickly; then follow muscles and nerves. Connective tissue and cartilage last longer, the horny tissues, elastic tissue (*e. g.*, in arteries, bronchi, lungs), hyaloid membranes, bones, and teeth last the

[1] A Text Book of Pathological Histology, by Prof. Edward Rindfleisch, translated from the second German edition, Phila., 1872, p. 23 *et seq.*

longest. As microscopical objects, finally, there are seen chiefly granular masses (albuminous molecules, fat-granules, pigment-granules), larger pigment masses, fat-drops, fat-crystals, cholestrin, crystals of the chloride of sodium, triple phosphates of carbonate and sulphate of lime, sal-ammoniac, leucin. Besides, there occur, according to the form of gangrene, various fungi (bacteria, mould-fungi, etc.). The chemical elements are butyric acid, valerianic acid, carburetted hydrogen, ammonia, sulphuretted and phosphoretted hydrogen, sometimes nitrogen, by which is explained the color and odor of gangrenous masses."[1]

There is occasionally developed during the process of gangrenous putrefaction, especially in cases of hospital gangrene, a slimy, pulpy, tenacious mass, which covers the entire diseased parts, through which the ichorous fluid is discharged; and in it there are sometimes mechanically retained some of the gases arising from the decomposition. I have frequently observed the same condition in the fauces, in cases of gangrenous diphtheria, a disease which is apparently closely allied in all respects to hospital gangrene. Both these morbid conditions engraft themselves on open wounds, and are generally indicated by the dotting of the same with blackish-gray points. The healthy secretion of the part is suspended. The edges of the wound are livid and slightly raised as the result of an accompanying inflammation. This condition of the borders of these wounds extends backward from them only a few lines, where it joins a broad erysipelatous areola, showing capillary congestion and stagnation. These ash-colored or blackish-gray spots generally increase in size until they finally coalesce, thus covering the entire surface of the wound and forming a part of the pultaceous mass which has been previously mentioned. The following observations, embodied in the report of Dr. J. J. Woodward, United States Army, presents the gross and microscopical appearance of this class of wounds. "In its destructive progress, hospital gangrene, as observed by me in these cases,

[1] Manual of General Pathology, by Prof. Earnst Wagner, translated from the sixth German ed., p. 348 *et seq.*, Phila. 1876.

appears to follow at least two diverse modes of extension, which, however, are frequently combined in different portions of the same excavation.

"I. On the one hand, the tissues immediately adjacent to the slough, which have been slightly reddened without being increased in thickness, become greenish-brown or black; the slough steadily progressing in this manner into the sound tissues, from which it is not separated as long as it continues to extend, by any pus-producing or ulcerative action or any true line of demarcation.

"II. On the other hand, the tissues about to be invaded become not only reddened, but hard and swollen, elevating the edges considerably, and causing, therefore, the cavity to appear deeper than it really is. This thickened mass breaks down rapidly into a fetid yellowish ichor and is thus quickly eroded, but in such a manner that the subcutaneous connective tissue is more quickly destroyed than the skin which overhangs, therefore, the jagged, irregular underminings of the morbid process. The sloughs in this case are ash-colored, yellowish or greenish-yellow, occasionally brownish or blackish, in which latter case it will generally be found that the dark color is due to the putrid mass drying into a species of scab.

"In both these varieties the slough attacks chiefly the skin and subcutaneous connective tissue and adipose layer. The second variety, however, more frequently than the first, may penetrate beneath the deep fascia of the part, still affecting especially the connective tissue septa, dissecting thus profoundly between the muscles and tendons, which resist longer the destructive process, and retain often their general form and appearance even after they have been completely undermined and separated, except at their extremities, from their normal connections.

"In the first variety an examination of the slough as close as possible to the living tissues showed nothing but the normal form elements of the affected part in various stages of putrefactive decomposition. None of the lymph or pus-forms which usually result from inflammatory action could be observed.

The small vessels and the capillaries of the living tissues near the slough were gorged with blood, which in the vessels immediately adjacent to the dead parts, was completely stagnant. In proceeding in the investigation of the sloughs of this character from the living tissues through the slough to the central cavity exposed by the disease, the elementary forms were found to be more and more completely obscured by the putrefactive changes until a granular opaque mass remained in which no formed elements could be observed, except perhaps a few yellow elastic fibres which had resisted decomposition. Associated with these changes was a tendency to break down into a fetid, diffluent semi-liquid, and thus to leave a cavity, which in this class of cases was generally bounded below by the superficial surface of the muscles of the part. In these cases it was generally observed that while the disease continued to spread peripherally, a line of demarcation was formed by a true ulcerative action with pus-formation between the superficial slough and the subjacent muscles, the pus being formed in at least some of the cases at the expense of the muscular tissue, as will be seen in the sequel.

"In the second variety an examination of the thickened and hardened edges into which the eroding process was extending, showed the tissues to be transformed into a mass of cell forms, of which the most numerous were spherical granular cells, quite identical in individual aspect to ordinary pus-corpuscles, but imbedded in a granular mass, and thus constituting what has been variously called croupous fibrin, croupous lymph, and corpuscular lymph. This is the condition described by Rokitansky as the 'death of textures replete with fibrino-croupous exudates,' to which category he refers hospital gangrene. Embedded in the same mass can also be seen occasionally connective tissue cells in various stages of enlargement and multiplication by division. By the liquefaction of the granular mass in which these elements are embedded they float out free, forming a scanty ichorous pus. The process, therefore, in this variety consists of two stages. In the first there is an extremely rapid cell multiplication, resulting in the formation of the innumerable

cells of croupous lymph with which the tissues are crammed; in the second the death of the infarcted tissues occurs either *gradatim* as an eroding ulcer or in mass as a bulky slough.

"In cases of either variety in which a favorable termination is attained after the sloughs are thrown off, granulations sprout up from the bottom and sides of the cavity and gradually fill it up. In one or two cases in which this process had advanced to commencing cicatrization nothing was observed different from what may be seen in the spreading of ordinary ulcers of considerable size. In many favorable cases, however, granulations sprout from the exposed muscles at the bottom of the excavation even before the extension of the sloughing at the margin is arrested."[1]

Having delineated the pathological changes which have been observed in traumatic gangrene, it now becomes necessary to mention the fact, that in many instances this affection is complicated by pyæmia or septicæmia. In these cases the pathological lesions which have been observed, are only those that characterize the septic diseases which have just been mentioned; and since these pathological conditions have already been described previously in this work, it does not seem necessary to repeat the description here.

SEMEIOLOGY.—The symptoms of traumatic gangrene, both local and constitutional, vary greatly in different cases. These variations chiefly depend on the variety of the disease, its extent, stage, complications, and the idiosyncrasies of the patient. In other words, it is known by observation, that the symptoms in cases of gangrene arising from urinary infiltration differ materially from those observed in hospital gangrene; and, likewise, that in the same form of this disease, the severity of the symptoms will depend on the character of the structures and the importance of the organs invaded, as well as the superficies of the morbid process. Furthermore the different periods of the same species of this disease are characterized by different symp-

[1] Medical and Surgical History of the War of the Rebellion, Part Third, Surgical Volume, p. 831 *et seq.*

toms. The nature and the extent of the lesion which preceded the traumatic gangrene and the character of the tissues on which the latter disease has become engrafted, will also determine in some measure the nature of the symptoms. The general principles enunciated in the preceding sentence are equally applicable to burns, frost-bite, tight bandaging, strangulation of a limb by the improper application of a tourniquet, scratches, contuso-lacerated gunshot, or incised wounds. A contusion may arrest the circulation and destroy the life in a thin layer of the soft tissues, which ultimately will be thrown off as a small slough, or the injury done may be so severe as to promptly cause the death of the whole limb. Thus, an extremity may be crushed by machinery, the passage over it of a cart-wheel, spent ball, etc., all circulation being immediately arrested, the vitality in the whole or a large part of the limb is simultaneously destroyed, the physiological action in the arteries, veins, and nerves is simultaneously suspended, producing a condition in which putrefaction must speedily follow, with all the usual symptoms of this form of traumatic gangrene. In another class of cases, where the injury has been less severe, the vitality of the parts is merely lessened, the power of resistance diminished, thus producing conditions which may be followed by marked œdema, blood stasis, and *finally gangrene*. This form of gangrene resembles that which arises from a too tight application of a bandage, inasmuch as it produces a *local traumatic mortification*, which commonly evinces no disposition to spread beyond the injured parts; and is soon bounded by a local line of demarcation along which it will separate. The mild cases of traumatic gangrene, where the injury has been done only to the soft parts, especially the bloodvessels, and where the gangrenous symptoms make their appearance after the lapse of some days, is commonly a strictly local disease, showing no tendency to spread; but "the true traumatic or 'spreading gangrene,' the most fatal variety of mortification, is most commonly the result of severe contused and lacerated wounds, particularly when complicated with fractures. It has a tendency to spread rapidly, especially through the areolar planes of the limb, often involving

the whole member in less than twelve hours after its invasion."[1] Hospital gangrene may attack any open wound or may occur during any stage of its existence, and the disease may assume either a mild or severe form, in which respect, the prevailing character of the epidemic may be expected to manifest itself in individual cases.

Local Manifestations.—It should be remembered that the symptoms in the different varieties of traumatic gangrene vary widely, as might be expected; since the different forms of this disease arise from entirely dissimilar traumatisms; but, nevertheless, whatever the form of gangrene may be, certain morbid conditions are common to all varieties. The temperature of the diseased part is lowered, it is cooler than that of the corresponding part on the opposite side of the body, and may be soon lower than that of the surrounding atmosphere. The sensibility of the part is changed. In some cases the patient suffers from an intense agonizing pain of a burning or neuralgic character just before gangrene makes its appearance, which is soon followed by the complete loss of sensation in the parts. It may then be handled and even cut without causing pain. *The power of motion is completely lost in the dead tissues*, although movements may be communicated to it by muscles from a distance, as a gangrenous foot may be moved by the unaffected flexors or extensors, but the parts possess no independent power of motion. The integument of the gangrenous parts becomes discolored, is commonly grayish, greenish, or brownish in the early stage, but gradually assumes a dull purplish greenish-black, which is commonly mottled with patches of reddish-brown. The epidermis of the discolored skin is generally removed by any indirect or oblique pressure, leaving behind the smooth, slippery cutis. The odor of putrefaction commonly makes its appearance in the early stage of the disease, while the liberation and retention of gases in the diseased tissues is very commonly attended with an emphysematous crackling. The local changes

[1] Erichsen's Science and Art of Surgery, from the seventh enlarged English edition, Phila. 1878, vol. i. p. 225.

in all cases of *moist gangrene* are essentially pathognomonic of this disease, and the dark purplish or greenish-black color of the affected parts, mottled with red, together with the putrefactive odor presents conclusive evidence of the nature of the morbid process. The local appearances in cases of dry gangrene are commonly well marked and radically different from those which have been just enumerated.

Constitutional Symptoms.—Constitutional disturbances may be entirely absent in strictly local traumatic gangrene, while in other cases, they may be observed in a mild form, and finally in the severest type of the disease these symptoms are commonly very severe. The amount of constitutional disturbance will depend *primarily* on the physical condition of the patient—the weak and sickly being more easily affected than the strong and healthy—and, *secondarily*, on the extent of the gangrenous affection and the nature of the tissue involved. It therefore follows that when gangrene attacks important organs, as the knuckle of intestine for instance, marked constitutional symptoms soon arise.

French authors recognize two distinct periods in traumatic gangrene, and their enumeration of the general symptoms of the disease is based on this division. The *first period* corresponds to the formation of the sloughs, and the *second* to their elimination. The first period is characterized by the symptoms of general debility or deep prostration, fever which may either intermit or remit, frequent and small pulse, a dull and anxious countenance, tongue brown, soon becoming loaded with sordes, insomnia, occasional delirium, anorexia, fetid diarrhœa, and, should hiccough supervene, it may be regarded as indicating a most unfavorable condition. When the gangrene is internal, sudden cessation of pain, with vomiting and tympanitic distension of the abdomen, may be superadded to the symptoms, and indicate the mischief which has occurred. Death is commonly ushered in with low delirium, twitchings, and coma. The *second period* of this disease, which commences with the throwing off of the sloughs and continues until the recovery is completed, is characterized, at first, by a gradual improvement in all

the symptoms which finally disappear during the restorative process. We recognize in the description just given all the characteristics of septic poisoning. In fact, true septicæmia is commonly associated with traumatic gangrene, and this may be easily explained, since the gangrenous tissues supply septic material which is immediately conveyed into the circulation, and consequently the septic symptoms may be even more pronounced than those of moist gangrene. The constitutional symptoms observed in all the severe cases of moist gangrene, are completely analogous to those produced by the injection of decomposing albuminous substances into the veins of animals. In that form of mortification called *gangrene foudroyante*, the progress of the disease is exceedingly rapid, and it always terminates fatally. This disease is in every respect an *acute septicæmia*, the absorption of septic material produces promptly the constitutional symptoms which have just been enumerated, while the local signs of gangrene commonly make their appearance *only a few hours before death or may be entirely wanting*.

In order to illustrate the peculiarities of this disease, I shall here present the outlines of a case which came under my care. The patient was an able-bodied police officer, aged about forty, who in the act of drawing a pistol from his pocket, had caused its premature discharge, producing a wound in the soft parts over the upper and anterior portion of the right femur. Thorough search was made for the bullet under strict antiseptic precautions, but with a negative result after which the Lister dressing was immediately applied. The examination and dressing of the wound followed immediately after the receipt of the injury, and the patient was quietly resting in bed at home, within four or five hours after the accident. The Lister dressing was removed within the next twenty-four hours, and no precaution *then taken against septic infection*. About forty-eight hours after the occurrence of this accident the patient was admitted to St. Francis Hospital, and was found to be suffering with *severe prostration*, fever, a small and frequent pulse, dull and anxious countenance, diarrhœa, etc. The patient became rapidly worse, while other and more grave constitutional symp-

toms soon made their appearance. The wound was discharging at the time the patient was admitted to the hospital a stinking sanious fluid, the integument surrounding the injured parts was slightly reddened, but there was no marked œdema or other important local signs. Thirty-six hours later the circumference of the *right thigh was more than twice as great as that of the left*, and the integument presented at various points a dirty brownish color, which was mottled in some places with red spots. The skin was now freely incised without causing pain, an operation which was followed by the escape of considerable stinking gas and the discharge of a fluid similar to that which has been previously mentioned in connection with the wound. Death occurred about four hours later. We have already considered the general characteristics of traumatic mortification; but it still remains for us to mention certain local peculiarities of a variety of this disease which is commonly designated *hospital gangrene*. It has been previously shown that hospital gangrene can only originate *de novo* under certain favorable circumstances; and the most important of these is the overcrowding of filthy and badly ventilated hospitals with unhealthy and suppurating wounds. The first premonition of the appearance of this disease is commonly given by the severe darting pains in the wounds, which have been compared to the pricking of a thousand needles, but in other cases the early stage of the disease is announced by a stinging or itching, while in some instances there is little or no change in the sensation of the parts.

Prof. Joseph Jones has graphically described the characteristic appearance of these wounds in the following, where he says: "In some cases, in the earliest stages, the wounds presented a dark red glazed surface; the granulations became altered in appearance, and rapidly disappeared; the discharge of healthy pus disappeared, and was followed by a reddish and greenish sanious fetid discharge. The parts around the wound became painful and swollen, and frequently a well-defined red and purplish indurated border in the sound skin surrounded the wound. The wound of itself rapidly assumes a swollen, ragged appearance (the gangrenous matter often being a few lines

above the surrounding tissues), with swollen, ragged, everted edges. With this infiltration of the diseased structures, and the consequent elevation of the surface and eversion of the edges of the wound, the glazed dark red appearance of the wound disappears, and the gangrenous mass presents a greenish and grayish color. When the wound was extensive, the gangrene would frequently appear in one or more circumscribed spots, of a dark gray and greenish color, and gradually spread over the entire surface, and destroy the surrounding tissues. I have seen extensive ulcerated surfaces in which the gangrenous parts remained almost stationary, whilst the surrounding portions of the wound presented a bright florid appearance. . . . . . During the active stage of hospital gangrene, the surrounding parts are swollen and infiltrated with serum, and the temperature of the parts immediately around the diseased structures is elevated somewhat above that of the parts beyond. As far as my observations extend, the serous fluid infiltrating the tissues is liquor sanguinis, and is capable of coagulation. The blood-vessels surrounding a gangrenous wound are always engorged with blood, as if the capillaries had lost their power to contract; and if an incision be made around the wound in the unbroken skin, these diseased vessels bleed freely. I have noticed in several cases of severe gangrene, that after serious hemorrhage the recovery of the patient was very rapid, as if the emptying of the surrounding engorged vessels had contributed to the rapid improvement of the wound. The deep purple and blue color of the skin surrounding gangrenous wounds which are spreading rapidly appears to be due to the want of oxygenation in the blood, and also to the fact that this blood is altered and contaminated, and in fact poisoned by the neighboring gangrenous matter. The deep blue and purple color in the surrounding skin is one of the most infalible signs of the active progress of the disease. After the disappearance of the gangrene, the blue and purple border either disappears entirely or else fades away."[1]
The constitutional symptoms of hospital gangrene are essen-

[1] U. S. Sanitary Commission Memoirs, Surgical, vol. ii. p. 147 *et seq.*

tially the same as those of the other forms of the traumatic disease indicating the existence of a septicæmic condition while they vary chiefly in the degree of their intensity.

DIAGNOSIS, PROGNOSIS, COURSE, ETC.—The diagnosis of traumatic gangrene can never be doubtful when the disease is fully developed, and its approach is commonly plainly foreshadowed by the precursory symptoms. The terms sphacelation and sloughing as applied to wounds are somewhat confusing, but it should not be forgotten that these conditions are properly included in the generic classification of *traumatic gangrene*. The prognosis in this disease may be either favorable or grave; and consequently no opinion should be expressed involving this question, unless it is founded on a definite knowledge of the individual case and its surroundings. It may however be observed that this remark does not apply to cases of *gangrene foudroyante*, since this disease always runs a rapid course and uniformly terminates in death. The gangrenous ulcers and bed-sores which make their appearance during the course of continued fevers, and which are properly regarded merely as complications of those diseases should be viewed from the general prognostic standpoint applicable to other forms of traumatic gangrene; and although it should be remembered that in those cases *the septic conditions precede the formation of these ulcers, therefore the constitutional symptoms make their appearance in advance of the local signs*, but this has no special influence on the prognosis. The *course of moist gangrene* may be brief or protracted, the patient may either speedily recover or die, and some cases have been followed by fatal collapse after apparent complete recovery from hospital gangrene. The course and termination of gangrene must depend on a variety of factors, such as the character of the lesion, the type of the disease, the vital power of the patient, and also the sanitary conditions by which he is surrounded. The recovery of patients from gangrene commonly follows promptly after the separation of the dead parts from the living tissues, while death in these cases generally arises from septicæmia which is due to septic contamination that occurs prior to the separation of the slough.

Prof. Ernst Wagner says: "Diffuse gangrene progresses either to the death of the individual, or it becomes limited and circumscribed. In a favorable termination, thrombosis calls forth in the gangrenous part a collateral hyperæmia of the surrounding textures, the gangrenous portion itself acts as an irritant on the surrounding tissues and causes inflammation of them. There appears the so called line of demarcation, *i. e.*, a lighter line of tissues, which has become hyperæmic and is suppurating. It follows for the most part the contours of the gangrenous mass. It is at first mostly superficial, but gradually deepens and finally separates the slough or gangrenous mass from the healthy structures. By a violent removal of the slough, light hemorrhages occur, which in a slow and spontaneous separation is prevented by thrombosis. The dangers of demarcation vary with the surrounding tissues, *e. g.*, typhous ulcer of the intestines, skin, lungs (in the latter almost always ichorous pleuritis and pneumothorax). The time which intervenes until the dead is wholly separated from the living structures varies greatly with the structure and the vascularity of the tissues. Demarcation takes place most quickly in very vascular soft ulcers, in subcutaneous cellular tissue and in the muscles, more slowly in the corium and mucous membranes, slowest in veins, fasciæ, and of all others in bones. The time depends also upon the volume of the gangrenous part and the general condition of the individual. The loosening or throwing off of the gangrenous parts most commonly occurs in necrosis of surfaces which are in contact with the air (skin, mucous membrane, lungs), if life has not previously been destroyed."[1] It might naturally be supposed that traumatic gangrene would frequently *terminate fatally during the process of sloughing, by the erosion of the arteries and the resulting hemorrhage, but this termination is almost unknown*; although the arteries are frequently uncovered, and even left entirely disconnected from the surrounding parts, and still they continue to perform their work seemingly without embarrassment.

[1] Manual of General Pathology, translated from the sixth German edition, p. 351 *et seq.*

TREATMENT.—The amputation of an injured extremity or the performance of certain surgical operations have a very important prophylactic bearing on the treatment of traumatic gangrene. It is an undeniable fact that if our surgical acumen enabled us to determine the extent and to understand promptly the character of the various traumatic injuries for which we are consulted, we would then have much less difficulty in the subsequent management of these cases; since the prompt removal of a limb, or the timely introduction of a scalpel, causing the escape of infiltrating urine, would *effectually prevent* the development of gangrene. It must be admitted that we are not infallible—that even the *best informed* and *most cautious* are liable to err—that uncertainty commonly leads to inaction; and therefore, that which was left undone immediately after the receipt of the injury must be remedied as far as possible at a later date. It may, nevertheless, be *boldy asserted*, that the present state of our surgical knowledge when carefully applied, enables us to apply prophylaxis in a highly advantageous manner, even in cases of severe injuries caused by machinery, railroad accidents, cannon balls, etc., but its greatest triumph has been the *banishment of war's greatest scourge—hospital gangrene*—which has probably caused more deaths among her devotees than any other septic wound complication. The prophylactic treatment of traumatic gangrene seeks to remove all the causes of this disease whether *general* or *specific*. It therefore takes cognizance of the patient's own person—wounds or injuries from which he may be suffering—the dressings for the same—bedding, furniture, and all other surroundings which may in any way produce this disease, or even aggravate it, when the same exists. It demands the highest possible degree of personal cleanliness, purity of air and proper nourishment; while the soldier, in order to escape hospital gangrene, must be properly protected on the field and in the prison, as well as in the hospital. All wounds should be kept in a perfectly aseptic condition, and where this is impracticable, *all those patients* should be isolated in order to prevent the development of hospital gangrene. It is even possible, when this system of treatment is strictly adhered to in the manage-

ment of wounds, for the dead parts *to be separated by a process of liquefactive solution, without the aid of putrefactive decomposition;* and consequently without endangering the patient's life by septic absorption.

I have frequently seen the flaps sloughing away, under the Lister dressing, without giving rise to a putrefactive odor, or any other indication of putrefactive changes. It should, however, be remembered, that, in these cases, the septic precautions were maintained in all their entirety from the time of the operation until the slough came away, and it is not even supposed that the application of a Lister dressing over a gangrenous wound already undergoing putrefaction would be attended by any *beneficial results.* In fact such a dressing ought never to be applied in gangrenous cases until the slough and every trace of putrefaction have been removed from the wound and its surrounding parts. It is not my intention, at this point, to enter into all the details of this dressing, or to describe definitely its applicability in the treatment of gangrenous affection; since the principles of this system *are presumed to be familiar to every surgeon,* and the success which will attend his practice *must depend on the proper application of the same.* Already monographs and books have been written on the principles and application of the Lister system of wound treatment; and consequently it does not seem necessary to dwell longer, at the present time, on these points. Having briefly suggested some of the advantages which may be gained by the proper prophylaxis in these cases there still remains for us to consider the CONSTITUTIONAL AND LOCAL TREATMENT OF THIS DISEASE.

The constitutional treatment of traumatic gangrene is essentially palliative, and not curative; although it is neverttheless *highly important.* The suffering patient may be freed from pain, lulled to sleep, and otherwise calmed by the proper use of an opiate. Stimulants and tonics may be advantageously employed during the whole course of the disease, in the majority of cases. Brandy, wine, and quinine are the most useful since they produce the most satisfactory effects. The diet should be nutritious and easily digested. Milk and animal broths

are entitled to the first place in this category. It should, however, be remembered that the above statements relating to the use of stimulants, tonics, and food can only furnish a general guide for the administration of the supporting treatment; since it is a well-established principle in the practice of medicine, that in every instance the article employed should be selected with special reference to the wants of the patient, based on the attending physician's knowledge of his condition and habits. This law applies not only to the selection of the article, but likewise to the quantity in which it shall be administered. The constitutional treatment should be so directed as to meet the important indications in each case, and, therefore, in addition to the medical agents which have been already recommended, it will become occasionally necessary to employ the mineral acids and iron. The muriatic, or nitro-muriatic acid may be advantageously employed, while the tincture of iron, or the *quiniæ et ferri cit.* may be likewise indicated. The constitutional treatment is essentially the same for hospital gangrene as in the other forms of traumatic mortification.

Local Treatment.—The local treatment in every form of traumatic gangrene is *highly important*, possessing a threefold character, viz., prophylactic, palliative, and curative. We have Prof. Erichsen's word for it, that: "Gangrene, when threatening as the result of inflammation, may often be prevented by free incisions into the inflamed and tense tissues. Punctures are not sufficient, but free incisions two or three inches long should be made, which by gaping widely allow the escape of blood and other fluids, and thus effectually relieve the vessels and the tissues. This is more especially the case when there is much loose areolar tissue, as in the penis and scrotum; or, indeed, in any part in which much tension is conjoined with the inflammation. The *relief of local tension* is of the first importance in cases of inflammation threatening to terminate in gangrene. By a free incision through the structures so affected, as in phlegmonous erysipelas or carbuncle, not only may the vitality of the affected tissues be preserved, but the extension of the gangrene, if it have already set in, may be arrested, and the constitutional

disturbance is at once lessened; the strain on the bloodvessels being taken off, the pulse falls, loses its sharpness, and great relief is afforded. In some forms of inflammatory sloughing, nature relieves the part by free hemorrhage, as from the dorsal artery in cases of acute gangrene of the penis; and it is not until this has taken place, that the gangrenous action becomes arrested. By incision, also, irritating effusions and infiltrations are discharged, and thus one cause of sloughing is removed."[1]

The chief objects sought to be accomplished by the local treatment of gangrenous wounds, are twofold, and consist in rendering them innoxious to the patient and those surrounding him, and likewise the promotion of rapid healing in the wound. The various topical agents which have been employed in the treatment of these cases have always been directed to the accomplishment of one or the other of these objects. The enumeration of all these remedial agents would require much time and space, and it would contain very little which would be of practical interest to the busy surgeon, who desires more *especially to know the best means by which may be accomplished the objects sought, rather than that which has been previously employed with very little or no success.* We have now reached that point in our study of the science of surgery where we are enabled to say, that, were it possible to *remove every particle of the necrotic tissues from a gangrenous wound*, and, from this time, *maintain the same in a completely aseptic condition*, that the object sought would thus be accomplished. Therefore the next questions which present themselves for our consideration are, Can this be accomplished? Is it practical? Unfortunately these questions must be answered in the negative in the majority of cases. It is certainly impracticable to remove all the necrotic tissues from a gangrenous wound, without removing, at the same time, a considerable amount of the living structures. We are therefore compelled to admit in the present state of our professional knowledge, that we have no method of procedure to recommend, *which will be perfectly satisfactory in all these cases;*

[1] Science and Art of Surgery, American edition, Phila., 1878, vol. i. p. 655.

but, nevertheless, *since we do know* that which is theoretically necessary, in order to *secure perfect results*, it therefore only remains for us to endeavor to secure the best results which are attainable under the existing circumstances. The pertinent question before us at the moment is, How shall we proceed in order to best accomplish our object? We recommend that the treatment begin with the removal of the dead tissues with the scissors and knife. The proper performance of this operation requires *patience*, *perseverance*, and *care*. The object sought to be accomplished is the removal of the dead tissues without injury to the living. There are many cases in which the operator can only be partially successful by this procedure, but in these cases he should supplement his first efforts by the use of bromine as recommended by Dr. Goldsmith, or the actual or potential cauteries.

While discussing this subject, I am satisfied that I can do no better, at this point, than to repeat the words of Prof. E. M. Moore, since my experience and opinions are in perfect harmony with those which he has expressed in the following words: "Many surgeons in the employment of escharotics have failed to find the benefit which they have produced in the hands of others. This may be explained by the different methods of application. The author, for instance, has seen bromine employed upon the surface of these gangrenous sores, with no benefit whatever; but when it has been used in a thorough and peculiar manner, immediate and rapid relief has been obtained. Failure has thus usually been due to the imperfect and inefficient method of applying the remedy. Bromine, first brought to the attention of the profession by Dr. Goldsmith, possesses the property of not only being somewhat caustic, but also of changing from the liquid to the gaseous condition. If, therefore, rightly applied, it has a power of penetration possessed by scarcely any other substance. If the gangrene, for instance, affect the skin and areolar tissue, no application upon the surface, unless it can destroy the slough itself, can reach the point of propagation. This is the border of the living tissue. In order to arrive at this, it is necessary that it should be cut,

which, perhaps, is best done by etherizing the patient, and dividing the areolar tissue with a pair of scissors beyond the line of the slough, so that the bromine can be introduced between it and the living parts. The peculiar quality possessed by this fluid caustic, of sinking into water without readily mixing with it, enables us to control it with great ease. The sloughs having been dissected off, the bromine can be brought to the surface of the still living tissue, as well as thoroughly mixed with the gangrenous pulp on its surface. The method practised by Dr. Goldsmith, of thrusting the point of a small syringe into the bromine at the bottom of a vessel containing water, enables the surgeon to fill his instrument with the drug in its pure state. The nozzle of the syringe can be readily passed into all the nooks and corners of the sloughing wound. The injection of bromine by this method fills the whole pulpy mass, which is immediately coagulated and which can now be readily removed, being firmer in its consistence and more amenable to manipulation. This being once effectually done, is usually sufficient to arrest the progress of the disease. If it does not, the failure will be readily recognized by the continuance of the fetor, which, disappears immediately when the work has been efficiently executed. . . . . Nitric acid, caustic potassa, and the actual cautery, are efficient enough, but are incapable of being applied as completely and safely as the mild escharotic, bromine, which, rapidly passing from the liquid to the gaseous condition, presses itself into the tissues in a way that no other caustic does. When the stump of an amputated limb is attacked, the space between the muscles must also be treated in the same manner as the subcutaneous tissue. It is surprising how rapidly the constitutional symptoms subside, when these measures have been carried out as described; a healthy granulating surface appearing as soon as the slough is thrown off."[1]

The wound having been brought into a healthy granulating condition will commonly continue to improve until cicatrization is completed, although the surroundings are only moderately

[1] International Encyclopædia of Surgery, vol. ii. p. 299 *et seq.*

favorable. No form of wound treatment is better adapted to accomplish the healing of the wound or can afford better protection to the life of the patient than the Lister dressing. The use of poultices and cerates, which were formerly employed so much in these cases, are unquestionably often injurious. The balsam of Peru, which is still recommended by some surgeons, is costly and likewise objectionable on account of the indelible stains made by it on the patient's clothing and bedding.

OSTEO-MYELITIS.

This term is generally applied to an inflammation affecting especially the medulla and the other surrounding tissues of the long bones. It was first employed by Chassaignac in 1853, in his description of acute sub-periosteal abscess and osteo-myelitis; but the author refers to the same disease which was first mentioned by Raynaud in 1831, as an inflammation of the medullary tissue of the long bones. It was not until 1836 that Gerdy demonstrated the fact that bones, like the soft parts, were subject to inflammation. Ancient surgical authors limited their treatises on the diseases of bones to caries, necrosis, and spina ventosa; although the lesions described under these names show some of the characteristic symptoms of osteo-myelitis. It likewise appears that Gerdy restricted his observations to the traumatic inflammation of the long bones which follow amputations and compound fractures, although he designated this morbid condition as ostitis. An examination of the literature of this subject renders it evident that this disease has been frequently described by different authors under various names, such as medullitis, endostitis, infective osteo-myelitis, and periostitis, primary infective osteo-myelitis, diffuse acute internal suppuration, osteo-myelitis, and necrosis, condensing osteomyelitis, syphilitic osteo-myelitis with gummata, diffuse suppurative osteo-myelitis, etc. The simple term osteo-myelitis is also frequently modified by the use of such words as *traumatic*, *idiopathic*, *constitutional*, or *spontaneous*. It will be readily observed that these terms are generally intended to convey an

idea of the etiology or pathology of this morbid affection, which has been shown to be an inflammation chiefly located in the interior structures of the bone, although occasionally involving its entire substance and even its periosteum with more or less of the surrounding soft parts.

ETIOLOGY.—The active agencies in the production of traumatic osteo-myelitis are now more thoroughly understood than they were twenty years ago, while the etiology of the idiopathic variety has not been so much advanced during that period. There is no longer any reasonable doubt that traumatic osteo-myelitis takes its origin from septic infection. "Dr. Koch has found micrococci in the pus obtained from osteo-myelitic abscesses, and he published his experiments with them in a recent issue of the *Deutsch. Med. Woch.* After cultivating them on boiled potato, he inoculated various animals, but failed to produce osteo-myelitis; when, however, a bone was crushed or fractured a few days before the inoculation, the disease was developed by them, which points to the rather instructive fact that, in order to produce osteo-myelitis of this acute infective type, not only must there be a specific virus in the system, but there must also be a local inflammatory process, or, if it be preferred, a local injury to the tissue, which becomes the seat of infective inflammation in the presence of the prime factor, the virus in the blood."[1]

The opinion here expressed in regard to the etiology of osteo-myelitis is greatly strengthened by numerous observers who have called the attention of the profession to the fact that this disease is practically limited to the overcrowded hospitals, and commonly soon disappears when the patients are removed from the badly ventilated wards and placed under canvas tents with suitable hygienic surroundings. It should, however, be remembered that even acute purulent osteo-myelitis may occasionally have had its origin under the most favorable hospital hygienic surroundings, when the traumatism and the constitutional conditions are favorable to its development. I have recently had a

[1] The Medical and Surgical Reporter, vol. l. p. 27.

case under my care in which the traumatism was followed by moist gangrene, involving the most of the leg, thus rendering it necessary that an amputation should be performed through the upper portion of the femur. This operation was performed the twenty-eighth day after the receipt of the injury. The original traumatism involved the soft parts of the thigh, but still there is no evidence that it extended to the femur. The patient was treated continuously in an atmosphere entirely free from any septic contamination other than that which was generated by himself, and he did not manifest, at any time, any symptoms of septic poisoning; but nevertheless the following illustration represents a typical case of *acute purulent osteo-myelitis* which has reached the stage of carnification. (See lithographic plate opposite page 680.)

It has been frequently observed that osteo-myelitis is seldom diagnosed until after death, and in this instance there were no symptoms of this disease, and consequently its existence was not even suspected prior to the amputation of the thigh. The patient had not complained of pain except occasionally at the knee-joint, and even about this articulation it was neither severe nor of long duration. There was not at any period after the receipt of the injury and prior to the amputation much œdema of the soft parts of the thigh; although there was extensive ecchymosis, and these tissues are known to have been severely contused. The character of the traumatism and the constitutional condition of the patient were unquestionably favorable to the development of osteo-myelitis in this case. The patient was about forty-six years of age, a wood engraver, and had been accustomed to the immoderate use of alcoholic stimulants twenty years. (He informed me at the time, that a slight excoriation, caused by an ill-fitting boot, a few years ago, remained unhealed six months.) The injury was promptly followed by traumatic gangrene, and the line of demarcation finally formed a few inches below the knee; but there was a severe lacerated wound involving the integument and other soft parts some inches above it. There was in this case unquestionably a certain amount of septic infection developed soon after the receipt

of the injury, but there were no marked symptoms of it during the period that the patient remained under my care. It is a well-recognized fact, that certain constitutional conditions act as predisposing causes of osteo-myelitis, and among these may be enumerated an unsound or impaired state of health, strumous habit, lymphatic temperament, syphilitic or cancerous cachexia, etc. It therefore follows that persons addicted to intemperance, or whose blood is impoverished by improper diet, continued suppuration, excessive fatigue or any other influence which lowers the vitality, must consequently predispose more or less strongly to traumatic osteo-myelitis. In this particular the osteo-myelitis does not differ from the other septic wound complications. In fact in all these septic wound complications, there are certain conditions which must exist before there can be developed such morbid processes as traumatic fever, septicæmia, pyæmia, and osteo-myelitis, etc.

In other words, the germs which produce these infectious diseases must find their way to the soil which is adapted to their reproduction. The literature of this subject leads us to suppose, that the disease which we now designate as traumatic osteomyelitis may have its origin in the medulla, endosteum, cancellated structure, or even the periosteum of the long bones. The question which consequently arises here in connection with the etiology of this disease, is: How do the facts which have been observed by Lidell, Allen, and others comport with the conditions which are necessary for the development of this disease? Dr. Thomas Bryant says: "When conoidal bullets, writes Longmore, happen to strike on or below the trochanters of the femur, they usually leave the head and neck of the bone intact, but cause fissures, which often extend to a long distance down the shaft; when they pierce the head, all the parts below usually escape fracture; when the neck is perforated the fracture generally extends both upwards and downwards. The same rule holds good with regard to the upper extremity of the humerus, although not in so marked a manner. In all these fractures, from the comminution of the fragments and the concussion the bone has sustained, osteo-myelitis and septicæmia are liable to

occur, as pointed out by Jules Roux, and Longmore."[1] It likewise appears that J. A. Lidell showed that gunshot contusions of the long bones are more fatal from this cause than comminuted gunshot fractures. It is now apparent to any surgeon familiar with the development of septic complications in connection with wounds, *that no more favorable traumatisms could possibly exist* than those which have already been pointed out in the quotation. The peculiarities of gunshot wounds favor suppuration and render natural drainage impossible or very imperfect, while decomposition and burrowing of the wound fluids have always been of very frequent occurrence. The wounds which have been mentioned, bring the decomposing wound-fluid into immediate contact with the parts which are involved in the morbid process, designated osteo-myelitis, and consequently, as might be anticipated, this disease frequently results from that class of injuries. Furthermore the injuries which have been inflicted on the bones will certainly act as a predisposing cause, while there can be no reason to doubt that when the inflammation has been once started in these parts, the results will be more unfavorable in those cases where the drainage is absolutely cut off from the interior of the bone. Dr. Allen expresses the opinion that, "It would not be unsafe to assert that, all things being equal, there is a direct ratio between the severity of a case of gunshot wound and the extent of injury to the bone. But, although the chances of recovery are generally proportionate to the slightness of the wound of bone, yet it sometimes follows that, from injuries primarily insignificant, fatal terminations follow. Thus, cases of tetanus have accrued from impacted balls in shafts; osteo-myelitis from mere scratches on the periosteum of long bones; and diploeitis and subsequent cerebral abscess result from a simple bruising of the cranium from a conoidal ball. The chief danger however is the occurrence of osteo-myelitis. This disease was originally detected in stumps, and was particularly noticed in cases of amputation of the thigh and arm, where the phenomena of the disorder could in part

[1] Bryant's Practice of Surgery, p. 951, 3d Am. ed. 1881.

readily be observed during life. Cases of fractures and resections have also furnished examples of the lesion. Yet the medulla of a long bone may become seriously involved even when the bone has not been injured, and the presence of such inflammation lies unsuspected during the life of the patient."[1]

In this respect traumatic osteo-myelitis resembles pyæmia, and the origin of this bone disease in these cases, it is thought, may be explained on the same principle as the formation of the pyæmic abscesses in parts of the body remote from the original wound.

That form of osteo-myelitis commonly designated by the adjective spontaneous, may probably be explained in some instances on the supposition that there exists in some part of the body a concealed wound, in which septic changes have taken place in the secretions, and from this nidus the secondary infection may have occurred. The same explanation is also applicable to certain pyæmic cases which are frequently designated spontaneous pyæmia. Prof. Billroth says: "On the whole, I am inclined to the belief that most of the spontaneously arising inflammations originate in peculiar fermentative processes in the tissues, but my observations at the bed-side have not led me to conclude that the ferment must of necessity be of a vegetable or an animal character. It is established beyond doubt, that the acute progressive septic inflammations can only be produced by inoculation, when the inoculated matter contains cocco-bacteria; further, that inoculations with septic matters not containing cocco-bacteria produces only symptoms of a more or less transient character."[2]

It has now been fully established that all cases of traumatic or infective osteo-myelitis have their *direct origin in an inoculation with septic matter which contains micrococci;* although there are numerous constitutional conditions which may act as a predisposing cause. M. Lannelong has called the attention of surgeons to the fact that, "the acute epiphyseal ostitis of

[1] American Journal of the Medical Sciences, vol. xlix. p. 30.
[2] Clinical Surgery, p. 419.

adolescence, pseudo-rheumatismal inflammation of bones and joints of infants, are in reality only cases of acute osteo-myelitis." This form of the disease is commonly classified as idiopathic osteo-myelitis, and is regarded as a primary affection; although dependent in the most of cases on a vitiated condition of the constitution, which acts as a strongly predisposing cause, while the exciting factor in the development of this inflammation is usually so unimportant in its character as to be quickly forgotten. Prof. Henry H. Smith, of Philadelphia, has called our attention "to the effect of fever on the sensibility of the medullary tissue of bone and the relief offered to 'pain in the bone' (as noted in the cold stage of intermittent fever and some of the exanthemata), by surface friction, the application of a tourniquet and other means of equalizing the superficial and deeper seated circulation. Similar results, indicative of the close connection and the reciprocal action of the skin and medullary tissue of bones, have been recently most positively established in England, thus, Mr. Savory reports a case in which the exposure of a limb to sudden extremes of heat and cold, by plunging it into ice-cold or very warm water, caused acute osteo-myelitis; and Macnamara, of Westminster Hospital, cites the case of a boy in perfect health, who fell through the ice Dec. 20, and on Feb. 15 suffered amputation at the knee-joint, in order to prevent further absorption by extension of evident septicæmia. Dissection of the limb showed that the cancellated tissue and medullary canal of the tibia were entirely destroyed, and that the outer shell (compact tissue) of the bone was more healthy than any other part; the myelitis being evidently not due to the extension of the inflammation from the periosteum to the medulla through the Haversian canals as might naturally be supposed. The close relation of the circulation in the skin and that in the bones, is also exhibited in the valuable tables of Gibney, of New York, where he cites rubeola, scarlatina, varicella, vaccina, and variola, with their respective sequences, as causes of bone and joint diseases, thus: 209 cases of spinal caries investigated with reference to this point, he found rubeola the exciting cause in 18 cases, scarlatina in 4

cases, vaccina in 3 cases, and in 106 cases of hip disease, the exanthemata were the exciting cause in 15."[1]

It must undoubtedly be admitted that tubercles in the bones exert an important influence on the development of the so-called idiopathic osteo-myelitis. Orth has described a cheesy osteo-myelitis which occurs almost exclusively in children in which the cancellated tissue is found filled with a cheesy material, in the vicinity of which small tubercles are plainly recognized.

PATHOLOGY.—We have already discovered that the term osteo-myelitis is applied to a great variety of morbid processes, which differ widely in their etiology and the points at which the disease originates; and it may therefore be naturally anticipated that the pathological changes will be somewhat varied. It should be remembered here, that our attention is especially directed in this chapter to the traumatic form of the disease, and consequently little space will be given to the consideration of the idiopathic variety. The pathology of traumatic osteo-myelitis will likewise in a manner depend on the character of the traumatism by which the injury was produced, although these differences may be justly regarded more frequently as a complication than otherwise; since a compound fracture of a long bone may take on the same sort of inflammation which follows in another case a simple contusion of bone. Dr. Lidell has called attention to the fact that: "The structure of the injured bone itself has also an important bearing upon the pathological condition produced by the contusing force. For this reason the marks of a bruise are much more obvious from the very outset in a bone having a loose, spongy structure, such as the condyloid epiphysis of the femur, than in one which is principally made up of compact tissue, such as the diaphysis of the same bone. Furthermore the pathological appearances produced by contusions in the spongy or cancellous osseous tissue bear a much stronger resemblance to a bruise of the soft parts, than the pathological appearances produced by contusion in the

[1] Trans. of the American Medical Association, vol. xxix. 1878, p. 185.

compact osseous tissue."[1] The pathological changes produced by osteo-myelitis may exist in the medulla, the bone, and its bloodvessels, and likewise in the periosteum and other surrounding tissues. The study of these pathological changes is best prosecuted when the disease is divided into three periods; *the first period* is characterized by a hyperæmia and cellular infiltration; the intermediate by the formation of a new osseous substance, while the last is indicated by its termination in resolution or by suppuration.

Any examination made during either of these periods should extend to all the tissues which are liable to be involved in the morbid process, especially the periosteum, the bone, and its bloodvessels, and also the medulla. The prevailing pathological peculiarities observed in the *periosteum* during the progress of osteo-myelitis consists of an abnormal vascularity and thickening of this fibrous membrane, which is due to the infiltration of these parts with blood and serum. The periosteum is also easily detached from the bone, owing to the presence of a reddish fluid between the inner surface of this membrane and the outer compact surface of the bone. This fluid appears to be a serous or plastic material, but the quantity is so small as not to permit an appreciable flow. The microscope, however, shows that it contains cells similar to those which exist in the normal state beneath the periosteum, but which are now greatly increased in numbers. These cells, according to Cornil and Ranvier, do not possess any proper cell membrane, and are only composed of an amorphous organic layer which they call protoplasm. They have given to them the "*nom d'embryonaire*" in preference to that of "*medullocelle*" employed by Prof. Robin; first, because they resemble those cells preceding the formation of the greater part of the tissues in embryo, also, because they are apt to make their appearance, under the influence of irritation which produces them and leads to their activity by sustaining or exciting around them the subsequent metamorphosis in connection with the new tissues, similar to those which have produced the

[1] The American Journal of the Medical Sciences, vol. I. N. S. p. 20.

primitive cells of the bone. We would add in this connection that the embryonic cells, which make their appearance in the first stages of osteo-myelitis do not uniformly give rise to a new bony formation, although this is frequently the result. They may abort, *i. e.*, disappear by resolution at the same time that the other pathological changes are effaced, and the periosteum will then gradually resume its normal anatomical characters. The important pathological lesions of bones, during the first period of traumatic osteo-myelitis, consist in the enlargement of the Haversian canals and in an increase in the size of the blood-vessels which supply the same. This enlargement is seen on the surface of the bone, while it is still fresh after the removal of the periosteum. It is indicated to the naked eye by the presence of a drop of blood at the openings in the bloodvessels which lead from the periosteum to the interior of the bone. The same may be seen when a transverse section of the bone has been made with a saw, or when a fragment is examined which has been broken off with a hammer. This lesion has been carefully studied and described by Gerdy, who has justly compared it to the hyperæmic congestion of the soft parts. But how is the enlargement of the Haversian canals accomplished? Gerdy claims that there is an absorption of the osseous tissues at the surface of the canaliculi, which enables the bloodvessels to continue to enlarge; but *he does not assert* that this absorption is the result of the pressure exercised by these vessels. He makes this assertion and apparently admits by silence that it is impossible to demonstrate satisfactorily the agency by which these changes are accomplished. In other words, he points out the fact, that the Haversian canals widen and the bloodvessels expand, at the same time without attempting to show that the one is the necessary result of the other.

Modern pathologists have not solved this problem; although Cornil and Ranvier have added something by their microscopic examinations to the former opinion, which was entirely based on examinations made with the naked eye. They claim to have discovered embryonic cells in the Haversian canals, analogous to those which have been previously mentioned in con-

nection with the periosteum, and which were mixed with other cells, poured out, they believe, from the osseous corpuscles which are also broken up. The correctness of this statement may be properly questioned, since, in every case, there is much difficulty in demonstrating the fact, that the liquid which is poured into these canals comes from the osseous corpuscles. It now seems to be a fact, that the microscope has demonstrated little more than the enlargement of the Haversian canals. German authors have made some attempts to explain this process, but all their efforts have ended in conjectures and hypotheses. Gerdy declares that the enlargement of the Haversian canals in osteo-myelitis is caused by the absorption of bone, which can only be explained by the peculiar nature of the inflammation. The medullary substance may be either primarily or secondarily involved in traumatic osteo-myelitis, although it probably never happens that the disease is limited to this substance. It is certainly impossible to determine, during the life of a patient, that an existing traumatic inflammation of the medulla does not, at the same time, involve the surrounding tissues; while in all those cases which terminate fatally the autopsies reveal the existence of ostitis and periostitis. It is, however, true, that, in some autopsies made on patients who have died of rachitis, and others whose deaths have been caused by certain febrile diseases, such as typhoid fever, variola, rubeola, and scarlatina, a longitudinal incision of the bone reveals an increased vascularity and consequently increased redness of the medulla, while there is also observed a diminution in the normal amount of fatty matter, without the existence of any evidence of a disease in the bony structures. The question may now be raised, whether this pathological state is that of the first stage of idiopathic osteo-myelitis? and if so, may it not follow a traumatism? In order to settle this point it becomes very necessary to determine that the *only existing morbid condition* is that which is described by Cornil and Ranvier under the name of *congestion et hyperæmie de la mœlle;* and, that it does not present on the cadaver any other pathological condition than that of an increased vascularity, and likewise that there did not exist during the life of the

patient any symptoms which could not be fairly ascribed to this morbid condition. Furthermore, the question may be fairly asked, in connection with our studies on the cadaver, if these changes are not simply *post mortem?* This question has not been answered, and is involved in obscurity, since the existence of these morbid conditions in life are not inconsistent with health. It is thought possible that a hyperæmia of the medulla may occasionally exist without involving the tissues of the bone and the periosteum; but, that in all cases of *true osteo-myelitis*, these parts do participate in the morbid process. This opinion is based on the *post-mortem* appearances which were observed at numerous examinations in cases of traumatic osteo-myelitis, and especially in those following amputations, fractures of various kinds, as well as the experiments made on animals. It may, therefore, be bodly asserted, that *true osteo-myelitis* is not simply a disease of the medulla, but it likewise involves all the tissues of the bone.

The question which now arises is, What are the lesions of osteo-myelitis in the soft parts?

The most striking to the naked eye is the deep red color of the whole or some part of the medulla. This is commonly the result of a dilatation of the normal capillaries, but may come in part from the formation of new ones. In some instances there are seen distinct points of ecchymosis in various parts of the medulla, which have arisen from the rupture of some of the capillary vessels. The redness is also more general or diffluent, from the fact that the fatty matter has been wholly or partially absorbed from the medulla during the early stage of the inflammation. In a more advanced stage of this inflammation the medulla is not only reddened; but is, at the same time, softened so much as to assume the consistency of cream. The composition of this mixture has not been determined, but it is supposed to be composed of the blood and other exudations arising from this inflammation. There is sometimes perceived, here and there, mixed with this reddened and more or less diffluent marrow, whitish, fibro-albuminous flakes or flocculi which are likewise developed under the influence of the inflammatory process. The

microscope has revealed in this mixture an abundance of the so-called embryonic cells of the same appearance and character as those observed in the Haversian canals and beneath the periosteum. Some of these cells are mixed with blood globules, but this generally happens in those cases where there is a marked degree of congestion and diffluence. In a few instances the microscope fails to reveal these leucocytes, and it is presumable, that, at this period, which is called the *plastic*, that the inflammatory products and even the embryonic cells may have been absorbed, thus restoring the medullary canal to its normal condition. The word *plastic* is here used with reference to an inflammatory condition, or stage of osteo-myelitis, which is attended with hyperæmia and a new cell formation exhibiting a marked tendency to resolution instead of suppuration or a gangrenous destruction of the parts. The clinical importance of this distinction arises from the fact, that while this inflammation is in the plastic state, it may terminate by the absorption of the plastic elements, or what is called resolution, or else it may end in the transformation of the inflammatory product into a tissue more or less resembling that developed in a state of phlegmasia. Therefore the so-called plastic inflammation does not endanger the life of the patient, or demand any active treatment for the purpose of circumscribing the disease; while, on the contrary, a suppurating inflammation commonly leads to certain destruction of tissue—occasionally to septicæmia and pyæmia—in any case it is of longer duration, and it always endangers the patient's life.

The second period of osteo-myelitis is the one in which the new bony deposits commonly occur. The formation of a new bony substance does not always happen in cases of this disease, but when it does it progresses rapidly at *first*, and likewise, in some instances, seems to advance steadily with the osteo-myelitis. This inflammation is characterized by an exudation about the bone, of a soft, semi-fluid substance, which hardens gradually, and finally becomes blended with the primitive bone. Modern authors consequently speak of this form of inflammation as *productive ostitis*. The new bony formation soon becomes as thick as the periosteum, and is commonly deposited between the peri-

osteal membrane and the compact layer of the bone, the former being essentially an osteo-genetic organ. It is not necessary to enter here into the histogenetic question relating to the new formation of bone, whether it be at the expense of the transformation of cells, or by the development of new ones; since the study is essentially the same as that which belongs to the formation of normal osseous tissues. It is, however, clinically important to know, that it is only on the surface of an inflamed bone that this osseous deposit takes place in excess. This overgrowth arises from a deposition of flakes, which primarily, more frequently become adherent to the periosteum than to the bone; thus are formed the bony pyramids or projections which are more or less prominent and likewise more or less numerous, and which have been designated by French authors as *stalactites*. The composition of the flakes and stalactites is everywhere the same, and it does not differ in this respect from the normal osseous tissues. The color of these deposits is the same as in healthy bone; but if a transverse section of the diseased bone is made, and the same examined and compared with its fellow of the opposite side, or an analogous bone taken from another subject, it will be perceived that the vitreous portion is thickened, increased in weight, and that the new deposit is non-vascular, which may be the result of the formation of new vessels, while there is a marked diminution in the number of Haversian canals; but these which are seen are commonly dilated and less crooked than usual.

At a later period the increase in the volume and weight becomes much more evident, and it is no longer necessary to compare the diseased bone with its fellow in order to see that it is remarkably thickened. Having called attention to the increase in the thickness of the long bones, it should be here added, that in certain subjects, there may likewise be produced an increase in the length of these bones. This increase in the length of the long bones never takes place in adults, but is confined to infants and children. It is shown by the writings of Hunter and Ollier, that the growth of the bone takes place between the diaphysis and the epiphysis, and the beautiful

experiments of Ollier have recently demonstrated: 1. That this is especially accomplished by the production of an osseous substance at the extremity of the diaphysis and at the expense of a corresponding surface from the epiphyseal cartilage; 2. That in a case where the inflammation and the vascularization have terminated in the early hardening of the effused fluid, the growth of the bone is arrested, while those cases where the prolonged inflammation has not terminated in the early hardening of the fluids, but which, on the contrary, has assumed a productive character, producing an abundant osseous secretion, may consequently end in an abnormal increase in the length of the limb.

The lesions of the medulla, during the second period of osteo-myelitis, are productive of a more highly organized fibro-albuminous exudation, or one which approaches more nearly to fibrous tissue than that of the first stage of this disease. There is also in the medullary canal a much less quantity of fatty matter than in the normal state. This is replaced by a whitish product, which is made up in the greater part of medullary cells; at the same time, that which remains of the marrow is vascular and reddened as in the first period of the disease. The proper inspection of the medulla requires that the bone should be sawn longitudinally or broken open by the blow of a hammer. There is frequently deposited within the medullary canal an osseous substance which may either occlude or narrow it. This new formation is not very compact, it is rather open and spongy, rarely found in large masses, more or less intermixed with the fibro-albuminous substance which has been previously mentioned, while the medullary tissue and all the other contents of the medullary canal are very vascular. There may be produced in osteo-myelitis an osseous substance within the medullary canal; but this deposit is always much less *within the bone than on the outer surface*, especially where it is situated near its diaphysis. The cases in which the deposit of osseous substance within the medullary canal are the most pronounced are those of fracture. In these cases the canal in both fragments is completely filled up with this spongy tissue from the

top to the bottom of the fracture; and the occluding material extends some distance into the canal. The same condition of occlusion follows the performance of an amputation.

The commencement of the third period of traumatic osteo-myelitis is characterized by the formation of pus; although it seldom occurs without having been preceded by abnormal vascularity, plastic deposits, and an increase in the volume of the bone arising from the deposit of osseous matter. The deposits of osseous material may be entirely wanting, or only exist in an embryonic state when the inflammation has progressed rapidly to suppuration. It should be here remembered that it requires several weeks to produce any considerable osseous deposit, and should suppuration take place before this has happened, it is to be expected that the changes effected in the normal nutritive material by the suppurative process will prevent all new bony formations. In the acute cases of osteo-myelitis it is presumed that pus may form within ten or fifteen days. It is indispensable for the full comprehension of the various pathological lesions arising from suppurative osteo-myelitis, to study successively the morbid anatomy of this disease, in the periosteum, compact tissues, and the medulla; and even in following out this method it is found very difficult to present an acceptable description of these morbid changes, since there are so many and such marked differences in these cases.

It has been observed in osteo-myelitis, that the inflammation is commonly found to illustrate different periods of the disease, in the same bone, at the same time, *i. e.*, in one portion of it the characteristic changes of the first period may be studied, in another those of the second, whilst still another part represents all the peculiarities of the third period. Furthermore, suppurative osteo-myelitis may readily pass into necrosis of the bone, a condition which will soon become complicated by the presence of sequestra. Finally it should be fully understood that the pathological changes are greatly modified by the acute or chronic nature of the disease. The most important pathological change in the periosteum, which characterizes the *third period of osteo-myelitis*, is the formation of pus, which may take place

on the outer or inner surface of this membrane. In the first case there is a marked thickening of the membrane, but the surrounding cellular tissue is also thickened, and it is frequently very difficult, or even impossible, to determine whether the suppuration primarily originated in the periosteum or the cellular tissue. It may, however, be reasonably inferred, that the suppuration has originated in the periosteum and not in the cellular tissue, when the external surface of the bone presents the vascularity of osteo-myelitis. There is little, if any doubt, that the *bone participates*, more or less, in nearly every periosteal inflammation; and, that this morbid process may likewise extend, in severe cases, to the cellular tissue; and, consequently, osteo-myelitis may be either a circumscribed or diffuse phlegmonous inflammation.

It is nevertheless certain that nearly every general rule has its exceptions; and, therefore, it ought not to surprise any one to learn that, in some rare instances, autopsies have revealed the existence of suppuration on the external surface of the periosteum without the existence of an inflammation in any other portion of the bone; but, on the contrary, the parenchymatous or plastic inflammation of the internal surface of this membrane will be *always found complicated* with an inflammation of the compact tissue of the bone and the soft tissue of the medulla. In the majority of cases of chronic osteo-myelitis and likewise in chronic periostitis, etc., which have finally gone on to suppuration, there is commonly found a deposit of new osseous material about the abscess, as well as at other points on the bone which have been inflamed. There are some points worthy of consideration in connection with these abscesses which form within or beneath the periosteum, and thus denude the bone. The first question which here arises is, What causes the disappearance of the periosteum? while the second is, Can it be reproduced? Prior to attempting an answer to the *first* question it is important to know that the various examinations which have been made of the contents of these abscesses have thus far failed to reveal any *débris* arising from the periosteal membrane; and, consequently, it has been thought that the

only satisfactory explanation of this *phenomenon* is found in the theory of an absorption, analogous to that which has been previously mentioned as occurring about the Haversian canals in connection with osteo-myelitis. It is not here intended to convey the idea that every trace of periosteum promptly disappears in all true cases of periosteal abscess; on the contrary, it is a well-known fact that in many instances the periosteum is merely ruptured, detached from the bone, and still adherent by its external surface to the adjacent muscles. The latter class of cases was carefully studied by Chassaignac, who believed that these abscesses were produced by a sub-periosteal inflammation. It is thought that the answer to the second question must be in the affirmative, although it unquestionably ought to be modified in order to prevent any misunderstanding. There is no reasonable doubt that the periosteum which has been destroyed by suppurating traumatic osteo-myelitis *has been occasionally reproduced*. I believe I have witnessed this occurrence in my own practice several times, and I find other surgeons asserting that the reproduction of the periosteum in their cases is a *well-established fact*. In some cases, especially of children, this suppuration is not followed by necrosis; but the restoration of the periosteum follows promptly its destruction. I have frequently witnessed the same process in adults in the case of scalp wounds, and likewise in compound fractures of the extremities. I now recall to mind the case of a compound fracture of the leg to which four surgeons were called in consultation, who unanimously agreed to amputate the limb, and the chief reason assigned for this procedure was the fact, that both the tibia and fibula were *so extensively denuded of their periosteum*, that the proper section of these bones would shorten the limb *at least four inches*. The patient very wisely refused, as the result shows, to have his limb removed; since he finally recovered with the leg but very little shortened, and that too without any important exfoliation of bone. The destruction of this periosteum had resulted from an inflammatory action started up subsequently to the receipt of the traumatism. During the first part of the treatment of the case the pus had been allowed to remain in

contact with the bone; but, soon after the consultation, there was established free drainage, and the naked bone was soon covered with a whitish substance tinged slightly with blue. This layer soon assumed a vascular appearance, when it resembled healthy granulations. James Paget quotes Mr. Hunter as saying: "I once scraped off some of the external surface of a bone of the foot, to see if the surface would granulate. I remarked the following day that the surface of the bone was covered with a whitish substance, having a tinge of blue; when I passed my probe in, I did not feel the bone bare, but only its resistance. I conceived this substance to be coagulating lymph thrown out from inflammation, and that it would be forced off when suppuration came on; but on the succeeding day I found it vascular, and appearing like healthy granulations."[1]

Third Period of Osteo-myelitis.—In the compact tissue of the long bones it is still necessary to distinguish two varieties of suppurating osteo-myelitis; the one terminates in necrosis, and the other in resolution. The latter form of this disease possesses the pathological characteristics of osteo-myelitis in its second stage. The pus does not collect in large quantities, and is principally in the Haversian canals. In order to examine advantageously the pathological lesions of this disease it will be necessary to divide the bone longitudinally, or else to fracture it with a hammer. The Haversian canals are now found slightly enlarged as in the first stage of osteo-myelitis, while the grayish, or sometimes sanguineous liquid is more abundant and somewhat thicker than the plastic fluid which is exuded during the same period, and in which the microscope reveals the existence of leucocytes. The purulent deposits generally occupy the natural cavities of the bone, which are not commonly increased as are the accidental cavities which are formed by abscesses in the soft parts. The second variety of suppurating osteo-myelitis, when it affects the compact tissue of the bone, is accompanied by necrosis. In some cases there is found on the surface, or in the substance of the bone, and more rarely in the

[1] Surgical Pathology, p. 155, 3d. ed.

medullary canal, an unusually compact piece of bone, which is either wholly unprovided with bloodvessels, or if any exist, they are few in number and very small in size. This dead portion of bone, or sequestrum as it is called, very soon assumes a uniform, pale, waxy, yellowish-white color, thus resembling quite closely the color of living bone, nevertheless the difference is so distinct that the ordinary surgeon finds no difficulty in making the differential diagnosis. The interesting pathological question which now arises in connection with the sequestrum is, What are the morbid changes which cause the death of this portion of bone? It is commonly admitted that the death of a portion of bone in these cases is directly due to the cutting off of the blood supply, thereby depriving the parts of the required nutrition. Is this change due to hypertrophy which diminishes the size of or occludes the Haversian canals, and consequently deprives the parts of the necessary blood supply? May it not arise from the accumulation of pus within the Haversian canals, and the pressure resulting from it on the bloodvessels? or does it come from a suppurative inflammation of these vessels which involves the osseous canals at the same time? It has already been observed that there is a form of suppurative osteo-myelitis which does not tend to the development of necrosis; and this fact would itself seem to constitute an argument against the query contained in the last two questions. This negative argument does not, however, answer those questions, and consequently there still remains an important problem to be solved by some ambitious pathologist. It must now be added that the necrosis having taken place, the suppuration becomes more abundant, the pus being increased not only in the Haversian canals, but also within the pyogenic membrane which separates the dead from the living tissues.

Suppurative traumatic osteo-myelitis in the medulla of long bones commonly announces itself by general and special characteristics. The general characteristics are, the presence of an ordinarily thick pus—slightly fluid—forming isolated deposits—generally circumscribed—occupying in some cases the entire thickness of the medulla; but more frequently found on its

outer suface. About these deposits in the medulla are found reddened points, ecchymotic spots, while the marrow is less grayish than in the normal state. Attempts have been frequently made to determine if the venous capillaries of the medulla are filled with pus during the suppurative stage of osteo-myelitis. Some have asserted that these vessels are too small to be properly examined, while others declare that they do not contain pus. It is, however, pretty certain that pus has not been found in them, although its presence was claimed by Blondin in cases of phlebitis of the medulla. However, *pus has been found* in the veins of long bones, *e. g.*, tibia and femur, in some instances in which the interior of the medullary canal was in a state of suppuration. This condition is very rare in suppurative osteo-myelitis, in fact, it properly belongs to pyæmia; and consequently should only be regarded as a complication of the former disease.

The question which now presents itself for our consideration is, What becomes of the pus which forms within the medullary cavity? In some of these cases the disease terminates in pyæmia and death, while in others the limb is amputated. There are still other cases in which the bone is perforated by the corrosive action of the pus; and it is likewise supposed that in a few instances a portion of the pus may have been absorbed, leaving behind in the canal a cheesy deposit more or less analogous to that which is seen in certain tubercular deposits. The development of these purulent deposits within the medullary canal in cases of suppurating traumatic osteo-myelitis is, sometimes, preceded by the decomposition of the wound fluids; although it frequently follows the receipt of a contusion of the bone and the soft parts which cover it. The traumatism may have been so slight as to cause but little inflammation external to the canal, while within it the inflammatory action was circumscribed and possessed sufficient intensity to produce an abscess.

SYMPTOMS OF TRAUMATIC OSTEO-MYELITIS.—These symptoms vary, and their variations depend to some extent on the existence or non-existence of a wound involving the soft parts, bone, etc. But, inasmuch as these variations belong to the

complications, and not properly to the disease under consideration; it is, therefore, thought, that we need touch but lightly on them here. In the case of any severe contusion there may be more or less laceration of the bloodvessels and nerves distributed to the periosteum, while throughout the whole of the soft parts, ecchymoses and other blood extravasations may be found. These lesions are soon followed by diffuse swelling and more or less pain when pressure is made over the injured surface of the bone. This tenderness, arising from pressure, can only be made available in those cases where the bones are superficial, as the anterior surface of the tibia, the great trochanter, the arch of the cranium, and other similar situations, otherwise the symptoms indicating the existence of osteo-myelitis will be marked by the œdema, etc. The symptoms of this disease and those arising from the contusion of the soft parts may promptly disappear; although there may have been a more or less marked hyperæmia and some exudative inflammation. If the termination is quickly reached by resolution, these symptoms of osteo-myelitis are promptly effaced and there remains no trace of the disease. But it is also possible for the disease to pass into the second stage in which there is developed an osseous substance. This stage is characterized by more or less continuous pain, and the pain on pressure persists after the symptoms of the contusion of the soft parts have disappeared; while, at the same time, there may be discovered some enlargement of the bone, marked at certain points by some perceptible unnatural prominences. The pain felt at this period of the disease is frequently very slight, and even the use of the limb is often but little impaired. The disease may still terminate in resolution which is commonly followed by the absorption of all or some of the osseous substance which has been recently deposited. In some cases the ossification in the new deposits has progressed too far for absorption to take place, and consequently the bone remains permanently enlarged in the portion which has been inflamed. In other cases, the osteo-myelitis pases from the second period into the third, or suppurative stage; in consequence of a septic inflammation having its origin in connection with the traumatism,

either by an open wound which communicates with the bone, or a more superficial one, with or without the formation of a scab. In some cases of suppurative osteo-myelitis there soon appear symptoms of the denudation of the bone and superficial necrosis. It is even possible, *although it very rarely happens*, for suppurative osteo-myelitis to originate independently of an open wound, in which case it is commonly designated by the adjective *spontaneous*. This form of the disease commonly makes its appearance in young subjects, who are strongly predisposed to inflammatory action, either by constitutional taint or temporary exhaustion. The effect of a slight traumatism on those enfeebled subjects may be compared to the blow which ignites the friction match in a powder magazine, since destruction in both instances may be expected to speedily follow. Heretofore we have only called attention to some of the more important local symptoms, and those which characterize the better marked form of this disease which is commonly designated as acute. In this form of osteo-myelitis there may be not only local but constitutional symptoms. The type of both the local and constitutional symptoms will generally depend on the *nature of the tissues involved* in the inflammation; and the morbid changes taking place in the parts, the latter being supposed to indicate the period of the disease.

The sensation of pain, which, in some cases, is the first indication of the existence of this disease, must generally depend on the nerve distribution to the parts. Consequently, when the disease originates in parts where the nerve supply is very limited there will be little or no pain, and on the contrary, should the nerve distribution be abundant, the pain may be very severe. It is therefore important to remember, in this connection, that *nerves are distributed very freely to the periosteum*, and very sparingly to any other part of the bone. The articular extremities of the long bones are much better supplied with nerves than the shafts, and consequently an inflammation of the medulla, or of the compact portion of the shaft, may pass unnoticed, which if located in the extremities would become painfully perceptible. It is also thought that the existence or non-existence of consti-

tutional symptoms may be frequently explained by the nerve distribution to the diseased parts. Therefore, when it is remembered that traumatic osteo-myelitis may have its origin in the periosteum, medulla, or compact substance, it then becomes very evident that the *disease may be either well marked, or not attended by any recognizable symptoms.*

The so-called syphilitic periostitis, or that disease which is more properly designated syphilitic osteo-myelitis, commonly makes itself known as soon as the periosteum becomes involved. An examination made, at this time, usually reveals a slight thickening of the periosteal membrane, the skin moves over it, but it is immovably fixed to the bone. The patient informs us that his attention was first called to the diseased spot by the local pain, and that he found the parts sore to the touch. This pain which was slight at first, gradually becomes more severe, and may become continuous, while it is almost invariably worse at night. The pain may be described as aching, acute, throbbing, or boring in character. When this disease attacks the bones of the cranium, it frequently gives rise to continual headache, and should a node form on the inner table of the skullcap, it may develop nervous symptoms, epilepsy, paralysis, etc., or if the deposit surrounds an emerging nerve, it may excite neuralgia and local paralysis; if the lesion is situated in the spinal canal, it may produce paraplegia. The syphilitic inflammatory action which occurs so frequently in connection with the tibia, involving sooner or later the surrounding soft parts, commonly commences beneath the periosteum and in the Haversian canals of this bone. The parts become engorged with blood. A sero-glutinous material forms which may raise the periosteum, local necrosis of the bone soon follows, the node may become large or small, hard, doughy, or fluctuating, the surrounding soft parts may become œdematous; but the patient rarely suffers, in these cases, with constitutional disturbances, such as a chill, fever, etc.

There are strong reasons for believing that the appearance of rigors, fever, etc., *commonly marks* in traumatic osteo-myelitis the commencement of a new era; although we are fully prepared

to admit that this disease in some rare instances is ushered in with constitutional manifestations. It is also quite apparent that the application of the term osteo-myelitis to so large a number of morbid conditions, which differ so widely in their general and special characteristics, strongly tends to embarrass and confuse those surgeons who have not studied carefully the different forms of this disease and its various complications. It is, I believe, true as stated by Dr. Ashhurst, that, "Even suppurative and gangrenous osteo-myelitis can rarely be recognized during life, unless the bone affected be in an unhealed stump, where the protrusion from the marrow cavity, of a suppurating or sloughing fungous mass, or an exploration with the finger or probe, would of course indicate the nature of the affection. Under other circumstances, the symptoms will be usually completely masked by those of the accompanying diffuse periostitis; if, however, as remarked by Dr. Lidell, the free incisions which were recommended for the latter affection should fail in any case to give relief, the surgeon would properly infer that the medullary canal was involved. A similar inference would be justifiable from the occurrence of pyarthrosis, or epiphyseal separation, or even from the pain and constitutional disturbance being more intense than could be accounted for by the existence of ostitis and periostitis alone."[1]

DIAGNOSIS, PROGNOSIS, DURATION, AND FORMATION.—The difficulties encountered in making a correct diagnosis, in many cases, of osteo-myelitis may be readily inferred from what we have already said, and the following by Dr. T. Holmes, who has tersely remarked that this disease "is more frequently recognized in *post-mortem* examinations than at the bedside of the patient."[2]

The prognosis of traumatic osteo-myelitis must be generally determined by the character of the disease, the nature of the complications, and the vitality of the patient. In explanation of this statement, it may be well here to add, that, even in cases of neglected compound fractures, where *this inflammation* has

[1] The Principles and Practice of Surgery, p. 557 *et seq.*, Phila. 1871.

[2] A System of Surgery, vol. iii. p. 746, 2d ed. Wm. Wood & Co., N. Y., 1870.

recently lighted up, the surgeon may confidently expect a favorable termination, if he promptly gives vent to the pent-up wound secretions and adopts the other necessary antiseptic precautions; but should he find the osteo-myelitis already complicated with pyæmia he may then justly anticipate an unfavorable termination. The study of the pathological changes in the various forms of osteo-myelitis renders it certain, that the duration of this disease must vary widely, in some instances reaching its termination within a few days, while under other circumstances even months may elapse before the end will be reached.

TREATMENT.—The study of the treatment of traumatic osteo-myelitis may be properly primarily considered under the heads of prophylactic and curative; while the latter is naturally subdivided into constitutional and local. The great value of prophylactic treatment in this form of the disease—particularly where there are open wounds—has been thoroughly demonstrated in the practice of antiseptic surgery during the last fifteen years. The reason why the antiseptic treatment is so completely satisfactory, as a prophylaxis, must be apparent to all, when it is remembered that traumatic osteo-myelitis is *essentially a septic disease;* and, consequently, to prevent its development septic contamination must be avoided. However, it is deemed unnecessary to enter here on a description of the details of the application of this treatment, since every surgeon is now supposed to be familiar with its principles and practice, and should any even desire to refresh their memories on this topic, they may readily accomplish their object by merely referring to other portions of this work. The antiseptic system is likewise adapted to the curative treatment of this disease, and may be frequently advantageously employed even after the formation of pus within or about the bone. In the majority of cases when an abscess has formed within, or about the bone, it becomes *highly important to liberate the pus, thoroughly disinfect the diseased and surrounding parts*, and these operations should be followed by the introduction of drainage-tubes and the other necessary precautions against septic infection. The liberation of pus within the bone is even more important than when it is

confined within the soft parts, and consequently no surgeon ought to hesitate to perforate freely the diseased bone in order to give vent to a pent up puriform collection. However, *it is not claimed* that every case of osteo-myelitis requires bone perforation, but it should generally be attempted in those cases in which there are abscesses within the medulla, or in the osseous structure; although in some of these instances the use of the trephine may prove that the disease of the bone has advanced so far as to require an amputation of the limb. Furthermore it is highly improbable, in any case of osteo-myelitis, arising in connection with a compound fracture, or an amputation, that it should require the bone to be trephined, in order to secure the necessary drainage; although it may be required, even in these cases, to incise the soft parts for the purpose of securing *free drainage* or relieving the tension caused by œdema. The object sought to be obtained by the antiseptic treatment of wounds is, the removal of the morbid *physiological irritation* on which the inflammatory process generally depends; but, it is likewise highly important to get rid of all mechanical irritants and foreign bodies which the wound may contain, such as loose fragments of bone, pieces of clothing, etc.; and the more promptly this is attended to, the better it will be for the patient. There are likewise also certain cases of the so-called spontaneous osteo-myelitis in which the disease is so obscure that the surgeon may be justified in making a free incision down to the bone, and even employing the trephine in order to settle the diagnosis. The surgeon, who would hesitate to employ these radical measures in any case, where the life or limb of his patient is endangered, and while the existing symptoms point to osteo-myelitis without being sufficiently marked to settle the question of diagnosis is unworthy of the profession which he represents.

Prof. T. Holmes has expressed the following opinion on this subject: "To obviate the formidable dangers, and the extensive disintegration of the parts connected with osteo-myelitis, it is justifiable in any case where pain in the bone, accompanied with the ordinary symptoms of acute suppuration (rigors, fever, etc.) but without signs of external or periosteal mischief, induces

a reasonable suspicion of this affection, to expose the surface of the bone by a free incision. Should the periosteum be found separated, or even separating, from the bone, the diagnosis of diffused suppuration in the cancelli will be rendered highly probable. When the separation of the periosteum has proceeded to any great extent, amputation of the member, or excision of the diseased bone is certainly indicated. It should be remembered that the disease is a rapid one, the fatal complications of internal phlebitis and pyæmia imminent; and, therefore, treatment to be effectual, must be adopted early. Medicine, as might be expected, has little effect on the disease; but the fever which accompanies it should, of course, be treated on the ordinary principles. In deciding on the question of removing the diseased bone (an operation which would in ordinary cases be held to be contraindicated if pyæmia had set in), it should not be forgotten how much the early symptoms of systemic infection resemble those of typhoid fever; so that it may be proper in doubtful cases to give the patient the benefit of the doubt, and attempt to relieve him from the source of irritation. In chronic osteo-myelitis the removal of the limb is frequently successful in affording the patient relief from an abiding source of irritation, which will at length otherwise prove fatal; but when this affection is limited to a portion only of the bone, the expectant treatment is indicated, and the patient may recover after the extraction of the sequestrum."[1]

Having now called the attention of the profession to the treatment of many of the different forms of osteo-myelitis; it still remains for us to comment briefly on the syphilitic variety of this disease, since it demands specific treatment. In these cases the surgeon's knife should be employed early; and, where there is any perceptible thickening of the periosteum, or œdema of the overlaying soft parts, it should be carried through the periosteum, dividing freely all the tissues down to the bone itself, unless this procedure is rendered impracticable by the situa-

[1] A System of Surgery, vol. iii. p. 747 *et seq.*, second edition. Wm. Wood & Co., N. Y. 1870.

tion of the diseased parts. These patients also require some constitutional treatment, and are generally greatly benefited by the use of the bichloride of mercury in combination with the iodide of potash. It should not be forgotten that all treatment, whether local or constitutional, should be employed for the purpose of limiting the morbid action, preventing septic contamination, suppuration, loss of limb, or the death of the patient from any cause. It is, therefore, necessary for the surgeon to carefully watch the disease in every period, that he may anticipate and take prompt measures to avoid any threatening danger. During the inflammatory stage of this disease, which is very rarely seen, it may be well to employ antipyretics; while in broken-down constitutions, or in cases of general debility from any cause, it may be necessary to employ tonics and other supporting treatment. The sulphate of quinine is unquestionably one of our best vegetable tonics, and likewise possesses considerable merit as an antipyretic agent; it is, therefore, peculiarly adapted to the treatment of these cases. Brandy, iron, cod-liver oil, and the mineral acids are likewise sometimes advantageously employed.

TETANUS.

DEFINITION.—This painful affection is commonly manifested by certain morbid sensations located beneath the lower jaw, such as stiffness of these parts, etc., which the patient usually attributes to catching cold; but tonic spasms soon make their appearance and progressively invade the neck, trunk, and extremities, being generally of a paroxysmal character and subject to more or less frequent exacerbations.

HISTORY.—There is no reason to doubt that this disease existed in prehistoric times, but it is supposed to have been first mentioned in Hippocrates's Aphorisms, and it was afterwards carefully studied by Aurelianus Celsus. Aretæus also gave a concise clinical description of it, to which the authors of the French compendium of surgery, after the lapse of more than eighteen hundred years, had very little to add. The Arabian authors

added nothing to the writings of the Latins on this subject, and we now pass over a long period before we find any additional contribution to the study of tetanus. Ambrose Paré, who lived in the sixteenth century, has only left an incomplete document on *spasms* and *convulsions*. Nevertheless he has described the three varieties of tetanus mentioned by Hippocrates and likewise predicted the cure of the disease. He invented an instrument to open the jaws, and should be regarded as the author of the antiphlogistic treatment by blood-letting and heat. He confined his patient in some hot place, as a room, and there, at intervals exposed him to the heat of a large fire or placed him in a hot bath. The surgery of Master Jean Legault, published in 1640, contained only confused notions of spasms, he did not even employ the term "tetanus." The wars of the sixteenth and seventeenth centuries served to attract the attention of surgeons to this disease as a complication of gunshot wounds. Trnka Kr'zowitz appears to have studied this subject most carefully in 1777. The analysis of the symptoms and the forms of the disease are pushed in his work to its last limits. Bajon, surgeon-major of Cayenne in 1777, has devoted several very interesting pages to this affection, which had made great ravages in French Cayenne. The above-mentioned author, in these writings, boldly claimed that a negro certainly cured tetanus with some indigenous plants of the country. He furthermore asserts, that the "truth which is always dear to me, compels me to admit that I have been an eye-witness to the recovery of several patients under his treatment, whom I had believed to be mortally ill." Dazille, in 1788, confirmed these statements of Bajon. There should also be mentioned many other authors who wrote during this early period more or less valuable contributions to the subject of tetanus. We now recall the names of Bilger of Strasburg (1708), Monroe of Edinburgh (1783), Clerke (1791), Hourteloup (1793), Burke (1794), Cothenius, Schmucker, Rodney, M. Gregor, Houck, Dupuytren, Fernel, Sauvage, Boyer, and others. It is probable that no surgeon ever had a better opportunity for the *careful clinical study of tetanus than was afforded to Baron D. J. Larrey* in the Egyptian and German wars under Napoleon

the first. It is likewise shown by his writings that he improved these opportunities, since he has given us one of the very best monographs ever written on the subject of tetanus. We search in vain at the present day for a better clinical description of this disease, through all the literature of the subject; although the works of Larrey have been considered by eminent authorities to be the connecting link between the surgery of the past age and that of the present time.

There was published a series of memoirs on the subject of tetanus by military surgeons which commenced in Africa with Baudens, Hutin, Guyon, and which include the latest statistics by Chenu in the Crimea and Italy. There is also found much in the German works bearing on this subject which has been recorded by the surgeons engaged in the Schleswig-Holstein and Franco-Prussian wars. Interesting memoirs have likewise been published on this subject by Colles, Poland, Taylor, and Yandell. The chief professional interest in the writings on tetanus during the last twenty years has been almost wholly directed to the pathology and etiology of this affection. Rokitansky may be regarded as the modern leader in these pathological investigations. He was followed in this work by Clarke, Joffroy, E. Wagner, Lockhardt, Dickenson, Vulpian, Michaud, Bouchard, Ranvier, Laveran, Amidon, Leyden, Benedikt, Charcot and Bouchard, Muron, Aufrecht, and Béclard. Hemholtz, Marey, and Charles Reichert directed their attention to the study of the muscular contractions in this disease and have given us a graphic description of true and false tetanus. They have supplied us with physiological indications on these essential points for the management of tetanus, both traumatic and idiopathic. It is to be sincerely regretted that their investigations have shown lesions so variable in their nature and frequency, so difficult in their interpretation, so questionable even in their existence, that some doubt, at this time, is still felt on all these points. We have now mentioned the names of some of the authors who have devoted their attention to the study of tetanus; but the particular work performed by each will appear in the subsequent parts of this essay.

CLASSIFICATION AND ETIOLOGY.—The causes of tetanus are unquestionably variable, or they *may be entirely dissimilar, and it must be admitted that they are not well understood.* Bauer has justly remarked on this subject, that "The knowledge of the etiology of a disease is but little promoted by selecting Latin terms to express the current views in regard to the causes which give rise to it, and attempting by this means to establish a classification. This is true of the early and pernicious etiological grouping of tetanus, which chiefly recognized four varieties: a traumatic, a rheumatic, an idiopathic, and a toxic tetanus. These designations, which are still in use, are to be rejected, if for no other reason, because they are in part given to diseases which are not at all related to tetanus, *e. g.*, to intermittent and hysterical toxic spasm."[1]

Another ancient classification of tetanus was based on the locality of the spasmodic contractions and the position of the patient. The following names were applied to designate these varieties: trismus, opisthotonos, and emprosthotonos, morbid conditions arising from the various contractions of the muscles of the jaw, neck, and chest. There has also been recently added to this classification another term, pleurosthotonos, a condition which arises from a contraction of the lateral muscles of the chest, giving the patient a lateral inclination. These muscles are usually attacked successively and not contemporaneously. Some surgeons have expressed serious doubt in regard to the existence of emprosthotonos and pleurosthotonos, and are therefore opposed to this classification. But Larrey recognized these varieties, and the medical press of the present day frequently report cases in accordance with this classification. The old methods of classification have been practically superseded by a more modern one which is intended to convey an etiological idea. It is well known that tetanus may arise from a wound, it being a source of nervous irritation. It is therefore called *traumatic tetanus*, and may be further designated by pre-

[1] Ziemssen's Cyclopedia of the Practice of Medicine, vol. xiv. p. 319, trans. Wm. Wood & Co., N. Y., 1877.

fixing it to the terms, *acute, grave, chronic,* or *mild.* Tetanus may also arise without a wound, and hence in recognition of the acknowledged agency of cold in its production, it is frequently called *tetanus a frigore.* An objection has been raised against the use of the *term traumatic,* because tetanus has occasionally occurred promptly after the healing of a wound. Should such a case be called *traumatic tetanus?* We fully recognize the fact that a wound may be an indirect cause of tetanus, even though it has entirely healed before the complication makes its appearance. It is believed that cicatricial impingement as well as other sorts of irritation of a nerve may cause tetanus, and consequently the objection to the use of the term traumatic in this instance does not seem to have been well taken. The terms idiopathic, spontaneous, and intermittent are frequently employed to designate certain varieties of this disease, but the power and scope of these words are so well known as to require little explanation here. However, the term intermittent is seldom employed in this connection, it is the *spontaneous tetanus* of the malarial district, a rare affection it is true, but one which seems to have been carefully studied, and its existence fully demonstrated by the physicians and surgeons living in the central part of France. In our examinations of the etiology of tetanus there are other varieties which might be mentioned in our classification, especially since they are probably more or less allied in their origin to the traumatic form of the disease. It is a well-known fact that the tetanus of adults is less grave in certain countries than that of the new-born infants. *Tetanus nascentium* produces terrible ravages in Cayenne and in certain maternities in the north of Europe. Its etiology is very obscure, although in some cases clearly associated with morbid conditions of the cord. Finally, in passing from infantile tetanus to that of adults, the puerperal form of the disease should be mentioned, which has been so well described by Blachez and Lardier in 1854.

Let us now bring forward a classification erected on a physiological basis, and join to this the etiological idea of the intoxication of the blood as a central or peripheral excitation. We

here include all the varieties recognized by Letiévant. The Lyons professor contends that tetanus embraces within its definition all cases of permanent contractions with trismus and general spasm of the muscles. He formulates the following classification:—

The Origin of Tetanus.

1. Peripheral.	Traumatic, Verminus.
2. Central.	From an injury to the medulla oblongata. From an injury to either the anterior or posterior portion of the spinal cord. From spinal meningitis.
3. Humoral.	From strychnia. From malaria. From uræmia. From lead. From vegetable intoxication.

These varieties of tetanus have a physiological existence, and in connection with them we ought to study also electric tetanus. The important question which now presents itself for our consideration is, Does every variety of tetanus arise from essentially the same influences, although different agencies seem to have been employed? The tetanoid symptoms produced by strychnine and electricity do not sufficiently resemble those of *true tetanus* to justify the conclusion that these morbid conditions are essentially the same as that observed as a complication of wounds. In fact we think it *may be very reasonably questioned* whether any of the agencies mentioned in the third order of our classification ever produce a morbid condition which *can even be regarded as a variety of tetanus.* Nevertheless, it is exceedingly probable, that, when other agencies have produced tetanus, the factors mentioned in the third order may exert a strongly modifying influence on the disease. It is highly important to know the various agents which are capable of pro-

ducing this disease, but *still more desirable to thoroughly understand their modus operandi in each case.* It must be admitted, unfortunately, that neither of these desirable points has yet been satisfactorily solved. We are frequently told that tetanus is produced by irritation of the nervous sytem, either peripheral or central. This assertion is *far too general;* and, therefore, entirely worthless; since every experienced surgeon knows, that, in the great majority of cases irritation of the nerves does not produce tetanus. In fact, it may be boldly asserted, without the fear of contradiction, that only in exceptional cases, does the pressure of a foreign body on a peripheral nerve-trunk, brain, or spinal cord, produce this disease, while inflammatory irritation of the cerebro-spinal axis likewise fails to produce the characteristic symptoms of this affection. We must, therefore, conclude, that tetanus *cannot* be caused by the usual forms of irritation; but, that *it must be specific in its character* and essentially uniform in its *modus operandi* in every variety of the disease. We believe this opinion is in perfect harmony with our modern physiology. Furthermore, that tetanus, whether of traumatic, *a frigore*, or spontaneous origin, in an adult or in the infant, male or female, acute or chronic, is developed in essentially the same manner and may terminate in death. The commencement of the disease alone varies; the different stages, the progress, and the termination are practically the same; and, in addition to all this, the pathological lesions in every variety of the affection are believed by clinical observers to be always the same. Having presented a few comments on tetanus in general, we shall hereafter confine ourselves to that form of the disease which develops in connection with a wound, and is consequently specifically designated by the term "traumatic."

The first question which presents itself for our consideration in this connection, is the etiological relation of a gunshot or other wound to tetanus. Is the wound the cause and the tetanus the effect? It is thought probable that these questions should be answered in the affirmative; although there are many reasons for supposing that the wound is only a predisposing cause of the tetanus. The fact that tetanus so frequently makes its appear-

ance in persons suffering from wounds, while the nurses and others living under precisely the same circumstances, with the exception of the absence of a traumatism, are absolutely exempt from this affection, furnishes at least *very strong presumptive evidence* in favor of the agency exerted by the injury in the causation of this disease.

It is also apparent from observation that the locality of the traumatism and its character exercise a marked influence on the development of this disease. In this matter we desire to call the attention of the profession to the following, by Dr. Geo. A. Otis, Surgeon U. S. A., who has informed us that during the late war of the rebellion, the whole number of wounds made by the weapons of war were two hundred and forty-six thousand seven hundred and twelve, while the entire number of cases of tetanus were five hundred and five, or a little over two in a thousand. "In the cases in which this complication was observed the seat of injury was: in the head, face, and neck in twenty-one instances, in the trunk in fifty-five, in the upper extremities in one hundred and thirty-seven, in the lower extremities in two hundred and ninety-two instances. The preponderating frequency of tetanus in the lower extremities, observed by Beck[1] and others, was very marked, over one-half of all the cases having occurred after injuries in this portion of the human structure, due undoubtedly to the massive layers of muscles and soft tissue, which prevent the surgeon frequently from clearing the track of the wound of foreign bodies and other obnoxious influences. Of the two hundred and ninety-two cases of tetanus in the lower extremities, the injuries were in the hip in two instances, in the thigh in ninety-nine, in the knee in seventeen, in the leg in ninety-five, in the ankle in twenty-two, and in the foot in fifty-seven instances; of the one hundred and thirty-seven instances in the upper extremities, the injuries were in the hand in thirty-seven, in the arm in thirty-four, in the shoulder in thirty-one, in the forearm in twenty-four, in the elbow in seven, and in the wrist in four instances. The belief

[1] Beck (B.), Chirurgie der Schussverletzungen, Frieburg, i. Br., 1872, p. 331.

that shot wounds of the foot and hand are particularly apt to cause tetanus is not confirmed by the cases recorded during the war. In the lower extremity, especially, this complication is found most frequently in injuries of the thigh and leg. In one hundred and thirty-one instances tetanus followed closely upon operations in the extremities, viz., one hundred and sixteen cases after amputations and in fifteen cases after excisions. Of the five hundred and five cases, four hundred and fifty-one, or 89.3 per cent., ended in death as follows:—

Summary of Five Hundred and Five Cases of Tetanus, indicating Seat of Injury and Result.

Seat of injury.	Total cases.	Recoveries.	Deaths.	Ratio of mortality.
Head, face, neck . . .	21	1	20	95.2
Trunk	55	5	50	90.9
Upper extremity . . .	137	18	119	86.8
Lower extremity . . .	292	30	262	89.7
Aggregates . . .	505	54	451	89.3

The recoveries after tetanus appear to have chiefly occurred in the cases of slighter or tetanoid forms, or in those in which the disease took a chronic course, and it is possible that the early application of powerful narcotics interrupted the progress of the malady in a few cases of acute form. From an examination of these cases it may be concluded that the later the occurrence of the disease after an injury, the better the chance of recovery; and also, that the longer the duration of the affection after its inception, the greater the chance of life. In the following table are indicated the days after an injury or after amputation on which tetanus made its first appearance:—

Statement indicating the day after Injury or Amputation on which Tetanus appeared.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Cases,	27	8	9	9	19	30	23	37	24	27	25	20	17	12
	15	16	17	18	19	20	21	22	23	24	25	26 to 30	Above 30	
Cases,	6	7	11	5	4	4	3	1	3	3	3	7	23	

In twenty-seven cases tetanus appeared on the first day; but twenty-one of these were cases of tetanus following amputations, so that in reality it only appeared in six cases within the first twenty-four hours after the original injury, and it may here be stated that, with the exception of a small number of cases, tetanus in cases of amputations invariably followed within a few days after the operation. Few cases occurred on the second, third, and fourth days after the injury; but from the fifth day, when sufficient time had elapsed for inflammatory action to manifest itself, the number of cases rapidly increased until the eighth, when it gradually diminishes again until the fourteenth, after which period tetanus appears irregularly, in one instance the malady not making its appearance until seven months after the injury."[1]

We have examined numerous tables intended to show the relative frequency with which wounds in various parts of the body are followed by tetanus; but since they do not differ very materially from those which have already been cited, we do not deem it necessary to reproduce them here. Unquestionably wounds of all kinds, even the most trivial scratch, or the most terrible laceration may be followed by tetanus; but it is not true, that all wounds are equally liable to this complication. It is

[1] Medical and Surgical History of the War of the Rebellion, Part Third, Surgical Vol., p. 818.

generally admitted, that, punctured, lacerated, and contused wounds, particularly in the hand and thumb, in the sole of the foot, or the toes, have a direct tendency to produce this malady. Dr. Gant has remarked, that, "Unyielding fibrous textures are peculiarly revengeful in this respect. Compound fractures and dislocations, rather than the simple form of these lesions, are threatening complications; and more so, if the fracture be oblique and playful among nerves and muscles, or if the dislocation be that of a ginglymoid joint, as the thumb. Gunshot wounds, involving possibly other forms of injury, rank high as causes. Amputation, as in the thigh, or the removal of a breast or testicle, are known causes. So also minor operations; *e. g.*, for fistula in ano, ligature of piles, extraction of a tooth, cupping, the irritation of a seton. *Diseases; e. g.*, gangrene, ulcer of the leg, a guinea worm under the integument, caries of the tibia. In obstetric practice; abortion, retained placenta. The influence of local causes in the production of tetanus is shown sometimes by the order in which the muscles become contracted; the muscles adjoining the seat of injury being perhaps first affected, as happened in a case of gunshot wound of the thigh under my care; and Billroth has seen tetanus confined to one limb, or even to one hand."[1] It is also probable that the general condition of the patient may have a predisposing influence favoring the development of tetanus. Furthermore, it is believed that any agent which keeps up a continuous nervous irritation has a tendency to produce this malady. Burns and some other injuries are supposed to act in this manner in the production of tetanus.

Prof. Frank H. Hamilton briefly states the causes of this wound complication as follows: "The predisposing causes are mental depression, climacteric influences, such as excessive heat, sudden vicissitudes of weather, and especially a rapid change from hot to cold and damp weather—it is more frequent in spring and autumn than in summer or winter—exposure of a portion of the body to cold drafts of air, an irritable tempera-

[1] Gant's Science and Practice of Surgery, vol. i. p. 338, second ed. 1878.

ment, physical exhaustion, disorder of the stomach or bowels, a scorbutic taint, etc.

"The exciting causes are wounds, especially compound fractures, in which spicula of bone press upon nervous trunks; wounds accompanied with unhealthy suppuration; gangrenous sores, and those which from neglect are not kept properly cleansed; laceration, contusion, partial division, or the ligation of a nerve.

"It has been known to be occasioned by cutting a nail or a corn too closely, by stubbing the toe, by abrasion from wearing tight boots, by a wound of the gums, by a laceration of the fourchette in labor, by the sting of bees, by the stroke of a schoolmaster's ferule, by salivation, the introduction of a seton, the injection of a hydrocele, the lodgment of a fish-bone in the fauces, the application of a scarificator in cupping, the ligature of arteries, ligature of the umbilical cord, burns, the excision of tumors. In one instance we have known chronic traumatic tetanus occasioned by the prick of a needle."[1] Clinical observers have gathered many facts pertaining to this disease; but its nature, which we shall discuss after having taken a cursory view of the morbid changes revealed by *post-mortem examinations, does not appear to be yet well understood.*

PATHOLOGY.—*The post-mortem* examinations in cases of tetanus occasionally reveal lesions which are apparent to both the naked eye and the microscope; but, they are so variable in their nature and frequency—so questionable even in their existence—so difficult in their interpretation—that doubt must still be permitted. Prior to the modern researches into the pathology of this disease—which only extends back about thirty years—it may be easily shown that many of these reports are filled with errors arising from the faulty methods employed in making these histological examinations. Demme, for example, whose thesis possessed a certain reputation, published at Berne, in 1859, an observation on hysterical tetanus, with conclusive micrographic analyses of the same lesions which he had

[1] Treatise on Military Surgery, p. 591 *et seq.*

previously observed in a case of traumatic tetanus. Demme made his microscopical examinations of the spinal cord twenty-four hours after death—cutting his sections from the *now* hardened tissue. It is sufficient to glance even casually at this work to be convinced, that it was done improperly, and that it is consequently worthless. Nevertheless there are recorded in the reports of *post-mortem* examinations made by the old surgeons many facts which ought to be preserved. Larrey wrote at the end of his campaign that "A sufficiently large number of autopsical examinations which, with the utmost care, we have ourselves instituted in different countries, but especially in the hospitals of Louvain, after the battle of Waterloo, of individuals whom we had caused to be dressed under our own eyes, and who afterwards perished from tetanus, have invariably presented to us well-marked vestiges of inflammation in the spinal marrow, with a more or less perceptible effusion of a reddish serum in the vetebral column."[1]

Curling in 1836, and Froriep in 1837, demonstrated in their turn, that the redness and inflammation of the nerves in the wound give rise to tetanus. Lepelletier had already declared, in 1826, before the Academy of Medicine, that tetanus commenced as an inflammation in a wound and extended from this point to the spinal cord. Commencing at this period, and very evidently without anatomical proof—the idea of a central inflammation following an inflammation of a nerve was admitted by Brera, Cavellino, Hanke, Stafford (1845), Zuffi (1851), and Chelius (1837).

Dupuytren, in 1834, cited a negative autopsy (there being no evidence of an inflammation in the wound), where, nevertheless, the vessels of the cranial dura mater were engorged with blood, as well as those of the spinal cord; as a small quantity of a light colored serum had accumulated in the arachnoid cavity of the cerebro-spinal axis. The surface of the spinal cord and the brain itself was slightly roughened. The muscles of the back were reddened and infiltrated with blood, while many of

[1] Larrey on Wounds, Phila. 1832, p. 59.

the muscular fibres in the posterior part of the neck were ruptured. The nerves of the wounded hand presented nothing extraordinary, although the median nerve seemed to present, throughout the whole length of the forearm, a somewhat more yellow tint than what is natural in the healthy state. The parts supplied with this nerve had been a little more sensitive during the course of the fatal disease than was natural. In *résumé*, we found nothing in the autopsy which enabled us to account for the phenomena observed during life. Matuszinski found in twenty autopsies, sixteen cases in which there was a semi-coagulated liquid in the rachidian canal. Liquid blood was deposited between the dura mater and the osseous canal. Tscharner (1841), Henock (1843), Vogt (1845), Clemens (1850), Kuhn (1854), all demonstrated the existence of congestion of the nervous centres and their membranes. At this time, Aronssohn, at Strasburg, called attention again to certain changes in the semilunar ganglion, demonstrated also by Swam and Carron du Villards. In the mean time the remarks of Lobstein on this subject, in 1825, are somewhat explicit. In the case of an amputation which was performed for tetanus, he discovered medullary congestion, while there was serum beneath the arachnoid membrane and a very distinct inflammation of the semi-lunar ganglion. The lesions of the great sympathetic have not been the object of investigation following tetanus; but in some cases the attention of the profession has been called to congestion and extravasation into some of the ganglions in the cervical region.

Gimelle (1857), recapitulating the alterations met with in fifty-two cases of tetanus, declares that twenty-nine presented lesions of the spinal cord and its envelopes, in three cases there were pathological changes in the brain, and in eleven the nerves and muscles were involved. It was about this time that there appeared in print the first report of the microscopical investigations made by Rokitansky and Demme, his pupil. Rokitansky concentrated his attention on the connective tissue of the spinal cord. Between 1835 and 1842, Cruveilhier figured in plates, sclerosis, showing the appearance of the connective tissue in

chronic inflammation of the spinal cord; but, according to him, tetanus, which destroys life by asphyxia, presents nothing abnormal either in the nervous centres or in the membranes overlying them. Demme made, in 1859, four autopsies in cases of tetanus and has given us the full details of his observations, which in spite of certain defects, that are inseparable from the first efforts in the field of science, still remain as models, and clearly delineate that which which was apparent to his naked eye. He describes with care the congestion of the medullary envelopes, the serous exudations, the hyperæmia of the membranes covering the brain, with the coagula in the sinuses of the dura mater, the bloody or serous effusions at the base of the brain beneath the arachnoid.

Following the attempt of Rokitansky, Lockhart Clarke, in 1864, and Dickinson, in 1868, in England, made the first regular and methodical examination of the lesions of the spinal cord. These investigations have had a decided effect on the professional mind and have gone far toward establishing the pathology of this disease. L. Clarke recognized the dilatation of the bloodvessels of the spinal cord. Around these vessels was deposited an amorphous exudation, compressing the normal tissues of the cord, reducing the size of the normal cells and the amorphous granules. More recently he has announced in another work, that he has already met with the same congestion and the same granular lesions, disseminated through the whole of the gray substance and its posterior horns. It has been claimed that these changes may have occurred after death, but Dickinson has been able to examine a spinal cord, in a case of tetanus, which was removed eighteen hours after the death of the patient and found all the lesions which have been described by Clarke. Ranvier, in 1870–71, had an opportunity to make four autopsies in cases of traumatic tetanus. The pathological specimens were removed from four to twelve hours after death, were treated in the most approved manner for hardening, and *were examined with the greatest care*, but he *entirely failed to discover any trace of disease in this organ*. The *negative results* of the examinations made by Ranvier, certainly diminishes the force of the positive

assertions emanating from Clarke and Dickinson. Charles Bouchard, in 1872, mentions the examination of a case where death occurred from tetanus, in which there was found in the brain a large quantity of leucocytes in the adventitious sheaths of the vessels. There was in the spinal cord an evident proliferation of the nuclear elements, which also existed in the adventitious tunics and the proper sheaths of the vessels.

Finally, the most grave condition was found in the increase of the connective tissue in the spinal cord, which consisted in oval nuclei surrounded by a granular and amorphous material. The cells in the anterior horns of the gray matter were deeply pigmented. The disease had reached the stage of pulmonary hepatization. Joffroy reported an autopsy, made in a case of traumatic tetanus, in 1871, in which there were found congestion of the meninges, sero-sanguinolent effusion, coagula between the dura mater and the osseous canal, and redness of the pia mater. The capillaries of the lining membranes of the ventricles were dilated so much as to be apparent to the naked eye, but the brain matter was unchanged in its appearance and consistency. Ogle, in 1869, in a case of traumatic tetanus, found the fissures of the cord, especially the anterior, filled with an exudation.

T. C. Allbutt, in 1871, reports the following pathological conditions in the spinal cord, which he observed in four autopsies; congestion of the vessels with thickening of their walls, hemorrhagic extravasations, granular exudations through the walls of the vessels, distension of the central canal with epithelium, yellow degeneration of the motor cells and granular degeneration in various situations. Michaud, in 1872, published some important pathological facts, relative to four cases of tetanus, which he had observed in the service of Cruveilhier, in which the examination was made by Charcot. Michaud admits in his *résumé*, an acute central inflammation of the connective tissue of the spinal cord, an exudation into the ventricles and lesions of the posterior gray matter. The degeneration was not always localized in the same parts of the cord, neither did it seem to depend on the locality of the wound. He also mentions atro-

phy and other changes in the peripheral nerves, but does not refer to the condition of their sheaths. Fox, in 1874, found congestion of the spinal pia mater, new cellular material on the inner surface of the dura mater, colloid degeneration of the white, and amyloid degeneration of the gray matter of the spinal cord. Aufrecht, in 1870, found lesions confined chiefly to the cervical region of the cord. Wood, in 1878, records the distension of the vessels around the central canal, and the existence of round bodies in the perivascular spaces and granular degeneration of the posterior horns. Broca has called attention to the congestion of the cerebro-spinal axis in cases of tetanus.

This congestion, according to Liouville, is generally found in the gray substance, *thalami optici*, *corpora striata*, and the convolutions. The *post-mortem* examinations made by Vulpian, in 1875, on patients who had died of tetanus, were essentially negative. He found neither blood extravasations nor leucocytes. He examined the medulla oblongata and other portions of the cerebro-spinal axis without meeting with any considerable alterations, while those observed were not sufficiently constant to be mentioned in connection with the symptoms.

Laveran, in 1877, made a *post-mortem* examination on the body of a patient who had died of tetanus following an amputation of the leg. He recognized in the anterior tibial nerve in the centre of healthy nerve fasciculi a fasciculous strangulated by a proliferation of connective tissue; this tissue was properly hardened and colored; and, it was then easy to distinguish it in the centre of the body of the nerve. The healthy nerve had been given a rose color while the diseased fasciculus presented a greenish-yellow appearance. Laveran was thus enabled to trace the diseased fasciculous upward some distance into the posterior tibial. Sections of the spinal cord were examined, but there was no abnormality in the gray matter or in any of the nerve cells.

Dr. R. W. Amidon, of New York, reports very carefully the following interesting case of tetanus: "Bertha B., aged 15, domestic, German. About 5 P. M., June 30, 1877, patient fell

46

two stories, received a contused and lacerated wound, 5 cm. long, extending transversely across the palmar surface of the right wrist. Through the wound protruded the lower extremity of the upper fragment of the fractured radius. There was also a slight contusion of the right ankle and back. . . . . Reduction of the protruding radius was attempted under ether, without avail." Three days later, "the protruding bone was cut off and reduction accomplished. The soft parts around the wound were in a gangrenous state." Six days after the receipt of the injury "the patient complained of pain and stiffness in the back of the neck, thirst and fever, and was very desirous of being fanned. Dysphagia or difficulty of swallowing now began to manifest itself, and tonic spasms of the sterno-mastoid and trapesius muscles.

"The patient died ten hours after the appearance of the tetanoid symptoms, and the autopsy was made thirteen hours after death. The median nerve was stretched and contused, and was of a green color. . . . In examining the sections, the first deviation from the normal structure was noticed in the pia mater. It was thickened and vascular. On its free surface there was a considerable recent exudation product, composed of fibrin, and cells, and everywhere in its meshes, especially around the bloodvessels, there was a great number of very large cells, . . . some fusiform and some multipolar, very coarsely granular, pigmented and with large oval nuclei. These cells are still better brought out by teasing a little pia mater when they appear as dark, granular, spindle-shaped cells, some 1 mm. long, whose large oval nucleus without a nucleolus appears like a vacuole. . . . . Carmine did not affect these cells at all. The next lesions found were hyperæmia and thrombosis. In many places the larger vessels seemed filled to repletion, . . . while at some points arteries, veins, and capillaries were so universally over-distended with blood elements, as to suggest the possibility of an embolic or thrombotic process. . . . . The vessel walls did not seem, as some have described them, thickened, but on the other hand thinned, from continued over-distension. There was seen at certain

spots enormous dilatation of the perivascular spaces, some of which were partly filled by a small-celled granular exudation from the vessel, to whose adventitia it was greatly adherent. The walls of these spaces presented a dense infiltrated margin. . . . . The next lesion consisted in cavities of various sizes in the nervous matter, some empty, others filled by a transparent, colloid material containing some small granules, but no cells or nerve débris. The small empty cavities may have been perivascular spaces from which the contained vessel had dropped out, but to the walls of the larger ones might be seen, still adherent, some of the colloid material. The walls of these cavities have an organized look, not a ragged disintegrated edge. . . . . The connective-tissue bands were enlarged, and the increase in the number of fixed connective-tissue cells was shown by the nuclear proliferation. The central canal of the cord was choked with desquamated epithelium, and there was a granular degeneration of some nerve cells.

"The first three sets of lesions named will be designated the meningeal, vascular, and cavernous, respectively. Having enumerated in general the lesions found in the present case, it will be seen that few of them present the charm of novelty, but it will be the aim of the present paper to elicit some new facts as to the hitherto unknown location of the already known lesions."[1]

Mon. F. Poncet states that some weeks after having examined the paper of Dr. Amidon, he had an opportunity to study the pathology of this disease; the subject being a young soldier, who had died of tetanus after having received a dislocation of the thumb, which was complicated with an open wound. The autopsy, made a few hours after death, showed extensive congestion of the meninges, ecchymosis, which did not disappear under a stream of water.

The spinal cord was cut into small pieces and placed in Müller's fluid, which was frequently renewed. After hardening the sections were made with care, and colored with carmine, when we were able to demonstrate very marked changes in the

[1] Archives of Medicine, vol. i. p. 270 *et seq.*

membrane of the vertebral canal, desquamation, vascular injection, foci of peripheral gray, granular disintegration, etc. It must be admitted that similar changes are frequently met with in the healthy state of the spinal cord, *but they were here more marked than usual.* But in the sections of the different parts of the spinal cord, neither the fasciculi, gray matter, nor the nerve cells were altered. There were no pathological changes in any portion of the medulla oblongata, either in the nerve fibres or nerve cells. The descending branch of the fifth pair of nerves was absolutely healthy. In regard to the vascular congestion we have not been able to discover any lesion in a great number of sections made in the medulla oblongata. These preparations were also examined by Mathias Duval, to whom the normal state of this region is so familiar, and the parts seemed to him to be absolutely normal.

Finally, sections of the median nerve and its collateral branches distributed to the thumb, were treated with osmic acid and showed no trace of inflammation, either interstitial or parenchymatous. The conclusions drawn from all these observations are unsatisfactory, since they are frequently so contradictory. In many cases the observations were made on the spinal cord more than twenty-four hours after death, while it is now a well-recognized fact, that the changes in nervous tissue occur earlier than in any other part of the body. Furthermore, decomposition always goes on rapidly in all diseases in which there is a rise of temperature after death, which is especially characteristic of tetanus. Having given a somewhat complete *résumé* of the recorded pathological observations, we now ask, is it possible there are no *post-mortem* lesions in tetanus? We dare not assert the affirmative. The contrary is probably true; but further investigation of this subject is very desirable.

NATURE OF TETANUS. — Having studied the pathological lesions as revealed in a large number of *post-mortem* examinations, we are now prepared to enter on the study of the nature of this affection. There are, at present, two theories put forth for the explanation of its origin and nature. *The first* assumes that *tetanus arises from an irritation of some portion of a peri-*

pheral nerve or nerves, with an increase of the reflex power of the cerebro-spinal axis. The second assumes that *the disease arises from a general contamination of the system by a special principle, causing the convulsive action.* The first hypothesis assumes that an irritation set up in the wound is rapidly propagated to the cord, where it establishes a reflex action, limited at its commencement to the base of the fifth pair of nerves, afterwards extending to the lower parts of the body, trunk, and extremities. This idea harmonizes with numerous observations, in which patients have very distinctly asserted that the aura commenced in the wound and ascended along the extremity. Furthermore, it has been recently observed in the treatment of this disease, that a slight irritation of the wound produces more or less well-marked general clonic spasms. Finally, this theory tallies so well with the idea of Colles, on spasms, as to apparently justify its application to true tetanus.

According to Brown-Séquard and Mitchel, it is peripheral irritation which originates and maintains tetanus. The former, however, does not believe that a painful irritation of the nerve is even necessary, because there exists a kind of antagonism by which the convulsive action is put in an inverse ratio to the sensitive conductility of the nerve trunk. Consequently, the pain, which at first thought, it would seem should necessarily follow the development of this disease, may be entirely wanting in the wound, without diminishing the reflex nervous action, which is sometimes more marked under these circumstances. It has been pretty well settled that inflammation of the nerve involved in the wound is not always an essential part of tetanus. Pain does not produce material changes which are perceptible in the nerves. Even the most painful neuralgia may not produce any permanent pathological changes in the nerve tissues. What, then, are the initial phenomena of traumatic tetanus reduced to its most simple expressions? *Simply a painless non-perceptible irritation.* The same answer applies with equal force *to tetanus a frigore* under the tropics. In this region, it is undeniable that this disease may be produced without the patient having experienced any painful sensation. How is the activity

of the cells produced in the spinal cord? Pathological examinations certainly justify the conclusion that tetanus is localized in the cerebro-spinal axis. Is the super-activity of the cells always connected with the congestion of the parts? Vulpian thinks that, in this condition, the circulation of the blood is not more rapid than may be advantageous to the organs; and does not see in this venous stasis the proximate cause of tetanus, nor the precipitating factor. He regards these pathological changes as secondary phenomena, as in the case of poisoning with strychnia. According to Brown-Séquard, there exists in tetanus an irritation of the gray matter, which is comparable to the state produced in the elements by the poisons which excite convulsions.

Vulpian, to whom microscopical examinations revealed very little or nothing, seems to incline toward the humoral theory. He admits the existence of pathological changes in the spinal cord, but has not been able to demonstrate them. He believes that tetanus is produced by a poison, similar to that which has been described by Panum, without however being able to demonstrate it. We reject the theory of Vulpian, the moment that we accept the theory of cerebro-spinal irritation. The theory of irritation is supported by the fact that there is frequently produced in tetanus a considerable rise in temperature, which it is thought may be explained on the basis of the morbid changes occurring in the cervical region, a portion of the spinal cord, in which physiologists have located the vaso-motor centres and the thermometrical regulators. It is undeniable, on the contrary, that certain cases of tetanus occur without any marked elevation in temperature. Consequently, the cerebro-spinal irritation, in the form which produces tetanus, must be regarded as the true cause of the disturbance in the temperature, except the elevation which may be caused by the muscular contractions. The theory which answers as fully as possible to our physiological knowledge of the functions of the nervous system, one which harmonizes with all the symptoms of tetanus, including those of the circulatory and respiratory systems, as well as the temperature of the body, is that which considers this disease

as *an exaggeration of the reflex nervous power localized in the upper part of the cervical region.* Giraldès, who accepts as radical and well confirmed the pathological lesions, regards tetanus as depending on a congestive irritation of the spinal cord and the medulla oblongata. He further believes that this congestion is occasioned by some functional disturbance in the vaso-motor nerves which come from the periphery. Between the theories of peripheral irritation and of general infection, we ought to mention one which was put forth, in 1871, by Martin de Pedro, of Madrid. According to him, tetanus should be regarded merely as a localized affection of the muscular system, or more especially as a disease of the connective tissues which surround the muscular fibres. He further asserted that tetanus is frequently complicated with endo- and pericarditis, a fact which has been demonstrated by *post-mortem* examinations. He proposed as treatment, hot baths, opium, and the iodide of potassium. *The humoral theory regards tetanus as the result of a general contamination of the whole system by a special poison generated in the wound or in the sweat.*

This theory rests on no chemical analysis, and has not been supported by any microscopical examination. It was born in England, when Benjamin Travers perfected the hypothesis of an infecting agent. It is maintained by Roser, Panum, and Richardson; Billroth is also of the same opinion as Roser, who has recently renewed the old comparison of tetanus with *rabies canina.* This view of the subject is supported by the marked similarity which exists between the symptoms observed in tetanus and those produced by poisoning with strychnine. The poison, soon after being introduced into the blood, acts on the cells of the spinal cord, increasing the reflex power at the point where this irritation ends, and kills the animal by exhausting the nerve-power. The supporters of the humoral theory declare that there is generated in the wound, or in the sweat, a poison similar to strychnine, which when introduced into the circulation, produces similar effects. We desire, at this point, to call attention to a hypothesis which has been accepted by a certain number of accoucheurs in explanation of puerperal tetanus.

Prof. Simpson observed that puerperal tetanus occurred more frequently when the uterine canal had been irritated, where there had been manipulation and hemorrhage, and remarked, it is not impossible that the production of a special poison by the retention of blood, or through the agency of a wound or something of this sort, may have given rise to the affection in these cases; but he did not furnish any important proof of the correctness of his opinion. Després, in 1870, declared that tetanus depended upon the introduction into the circulation of an infectious agent, which is generated in a traumatism, and in connection with this statement he called attention to the initial chill and grave fever which occasionally announce the commencement of fatal cases. It is, however, believed that the humoral theory has no support which is tenable. It was, in a measure, disproved by the experiments of Tripier and Arloing, who injected horses with the blood taken from an animal which had died of tetanus, without reproducing the primary affection. Therefore the poisonous principle *does not* exist in the blood. It likewise seems to have been demonstrated in the practice of aseptic surgery, as well as otherwise shown, that putrefactive decomposition has no agency in the production of this disease, since in numerous cases of open wounds, where Listerism had been strictly adhered to, notwithstanding these strict precautions, tetanus has developed. Furthermore, we are in possession of the most convincing proof, showing, that tetanus frequently arises independent of any traumatisms, or even after cicatrization has been completed. Molkiewitzs regards tetanus as a paralysis of the reflex centres, the seat of which should be in the *corpora quadrigemina;* but, in man, this point has never been demonstrated. Finally, Will. Forbes, who has employed the nitrite of amyl—in the treatment of tetanus—uses it with the intention of producing an alteration in the muscular nutrition. The hyperæmia and the troubles in the circulation, lead to an accumulation of lactic acid and creatinine in the muscular substances, a source of irritation to the terminal nerve branches.

Chemistry has made some interesting discoveries in the field which now occupies us, showing that there certainly exists in

the economy a poisonous alkaloid made by the organism. The *ptomaïnes*, produced by cadaveric decomposition—first studied in Italy—afterwards in France, by Arm, Gautier, Boutmy, and Brouardel, possess in an infinitesimal dose a frightful power. Arm and Gautier have been able to demonstrate in the normal urine another poison, which possesses considerable toxic energy—stupefying and tetanizing animals—killing with the heart in systole, etc. This substance possesses the principal properties of the *ptomaïnes*—which acts by rendering the heart beats irregular—in leading to stupor, tetanus, and death.

SYMPTOMS.—In our consideration of the symptoms of traumatic tetanus, it will be necessary for us to remember that this disease is naturally divided into an *acute and chronic form*, although the essential manifestations of this affection will be found to differ more particularly in *degree* rather than in *kind*. Traumatic tetanus is likewise divided into three periods, which may be conveniently designated as the formative, active, and terminal stages, while each of these divisions is characterized by symptoms peculiar to itself. The time which elapses after the receipt of the traumatism until the appearance of the first symptoms varies greatly; although it is generally from five to twenty days. Nevertheless, the disease has been known to manifest itself within a few minutes after the injury, and in other cases months have elapsed before it was developed. In these cases, the wound fluids may become scanty and ill-conditioned—a border of the integument surrounding the wound may be reddened—this morbid appearance extending gradually upward toward the base of the limb—the diseased skin presenting a a dark, livid color—this morbid condition resembling neither erysipelas nor lymphangitis—slight tingling or burning sensation may be felt in the wound—darting or shooting pains may be felt,—*e. g.*, in the cases of a wound of the finger, along the inner border of the forearm—gradually extending up toward the spine. Other trivial symptoms are often mentioned by the patient, after the development of the disease, which were so slight as to scarcely attract the attention of the patient at the moment of their occurrence. The patient soon complains of a

slight pain in front of his ears—a little stiffness in the temporo-maxillary articulation—and commonly attributes these sensations to having taken cold. These premonitory symptoms are generally noticed immediately after awakening from sleep. Other ill-defined disturbances of the general health—the so-called rheumatic pains which are not easily defined—may also be noticed sometimes previously. Acute traumatic tetanus may be ushered in with a chill, although this precipitate form of the disease is seldom seen. About the same time that the stiffness in the temporo-maxillary articulation is observed, there may be some twitching in the muscles of the affected limb—painful contractions which are generally fugitive and sharp—rendering the patient restless. Nevertheless there is no fever, the pulse is commonly about seventy, and the temperature, which is now dependent on the traumatic condition, may be slightly lowered or remain normal. The pain in front of the ears and the temporo-maxillary stiffness mark the commencement of the active stage of tetanus. *The patient now becomes worse with frightful rapidity.* The neck becomes stiff—pains shoot down the back—through different parts of the face and neck—and while he is making an effort at deglutition the *first* decided paroxysm makes its appearance.

The pain and stiffness of the face and neck are commonly observed on the side corresponding to the wound. Fever commonly makes its appearance at this stage of the disease, but it is generally moderate, and probably dependent on muscular spasm. "When a muscle falls into a state of contraction it not only becomes demonstrably warmer, but there is in truth more heat produced in the acting muscle. The increase of temperature during muscular action is found not only in the muscles themselves which are in action, but also in the whole body; but in the body collectively the increase is very slight."[1] The disease having fairly entered upon the active stage generally steadily advances; "a severe and fixed pain shoots from the

[1] Ziemssen's Cyclopædia of the Practice of Medicine, vol. xiv. p. 349, trans. Wm. Wood & Co., N. Y., 1877.

ensiform cartilage to the back, accompanied with difficult and convulsive breathing, in which the muscles of the glottis are also implicated; the walls of the abdomen are hard, the bowels constipated; urination is difficult. Sooner or later all the muscles of the body become rigid, constituting true tetanus; or the muscles of the back being most violently contracted the patient rests only upon his head and heels, a form of spasmodic contraction which is termed episthotonos; more rarely the incurvation takes place in the opposite direction, constituting emprosthotonos: and still less frequently a lateral incurvation is observed, which has been called pleurosthotonos. In well-formed cases these spasms may occasionally relax, but they never completely cease. The pupils are contracted, froth escapes from the mouth, while the teeth remain firmly closed; and in the distorted features agony, pain, and despair alternate with sardonic smiles. Obstinate and persistent constipation is invariably present. The pulse, except when accelerated by the violence of the spasms, remains undisturbed. But the most appalling circumstance of all is the fact that, during this frightful agitation of the body, the functions of the brain are generally unimpaired, and, like a mariner in the midst of a storm, the mind of the suffer is the conscious witness of the writhing and tossing of the vessel whose speedy wreck seems inevitable.

"As the case approaches a fatal termination the paroxysms become more frequent and violent, and the breathing more embarrassed, until at length the patient dies in a state of exhaustion or of suffocation.

"Death generally takes place on the third or fourth day, sometimes as late as the eighth, tenth, or twelfth day; but if life is prolonged beyond this, recovery may be generally anticipated. Occasionally it has been observed that the spasms commence and are throughout more violent upon the side corresponding to the wound; and still more frequently is it noticed that in the early stages the spasms are confined to the muscles in the neighborhood of the wound."[1]

[1] Hamilton's Treatise on Military Surgery, p. 593 *et seq.*

Prof. Hamilton, in his vivid description of this disease, has omitted to state that these unfortunate victims frequently suffer greatly from thirst. The thirst is unquestionably dependent on the loss of water through the skin and the difficulty in swallowing liquids. The appetite may be craving, there is commonly most acute hunger, and the food is well borne, so long as the patient is able to take it.

An examination of the urine occasionally shows the presence of albumen, sugar, or even casts, but these substances should be regarded as a novelty; since they are seen only in exceptional cases. Renal affections may exist at the time the patient is attacked with tetanus, and it is even possible for it to arise during its course, but there is no reason to regard them as an essential part of the malady which is now under consideration.

We will briefly call attention—without theorizing—to the fact that tetanus is frequently characterized by a high temperature which comes on a few hours before dissolution takes place, which becomes even higher after the death of the patient and continues above the normal several hours.

Diagnosis, Prognosis, and Course.—During the prodromal stage, it is very rarely, if ever, possible to diagnose accurately the forthcoming disease; but with the appearance of those symptoms which characterize the commencement of the active stage of this affection, there will be found no difficulty in effectually settling the question within the first twelve hours. The active stage of this disease is characterized by pain in front of the ears, stiffness in the temporo-maxillary articulation, which steadily increases until the patient can no longer separate the teeth, complete absence of fever during the first twenty-four hours, tonic contractions, which progressively involve different groups of muscles, followed by severe paroxysms of short duration; the patient preserves his intelligence, has no delirium, sleeps at intervals, is easily disturbed without its producing any increased spasmodic action, commonly eats well during the first twenty-four hours. There is no paralysis during any stage of the disease. These symptoms point clearly to the existence of tetanus and to no other disease when properly understood and

collectively and carefully examined. In former times it was thought that tetanus might be mistaken for hydrophobia, for the reason that the spasms of the former disease occasionally affect the muscles of deglutition and give rise to difficulty in swallowing; while it is true that there may be difficult deglutition in both these diseases, it is equally true, that none of the other symptoms in tetanus bear any marked resemblance to those of hydrophobia. Hysteria may imitate tetanus, but, like other counterfeits, when your attention has been once called to this fact, its true character is easily determined.

The symptoms arising from poisoning with strychnine may give rise to some trouble, since it "is the poison with which we are most familiarly acquainted, as bearing the closest analogy in its symptoms and effects with those of tetanus. The symptoms produced in animals are general uneasiness, convulsions of a tetanic kind, muscular rigidity, arching back of the head and neck, violent stretching of the legs, and spasms brought on by the slightest touch like a galvanic shock. The symptoms, as it affects man, are agitation, trembling, tetanic convulsions, spine and neck bowed, arms stretched out, hands clenched, the stiffness when once set in never entirely disappearing; recurrence of first paroxysms and reappearance of jerking rigidity; retraction of the muscles of mouth and face; the countenance suffused and red, and the pupils dilated. The patient can open the mouth and swallow; there is no locked-jaw, but spasm of the respiratory muscles; terror of suffocation; laryngismus early, sudden, and intense; consciousness retained to the last; senses unnaturally acute; calmness. The time of acting is, in small doses, half an hour to an hour; in large doses about ten minutes. In large doses, death ensues in a quarter of an hour; in small doses, from half an hour to an hour."[1]

PROGNOSIS.—In the acute form of traumatic tetanus the prognosis must still be regarded as *very grave*, while the chronic cases frequently recover. It is, therefore, apparent that the

[1] Holmes's System of Surgery, vol. i. p. 324 *et seq.* Wm. Wood & Co., 1869.

prognosis of tetanus will depend on the intensity of the tonic contractions, their generalization, and especially the rapidity with which the contractions are followed by general spasms. Furthermore, a surgeon would not venture to express an opinion in regard to the prospects of any case of this disease until he had examined carefully the character of the patient's pulse, determined his temperature, and was fully satisfied in regard to the physical ability of the patient to cope with the depressing effect of the disease. So great is the mortality in *acute traumatic tetanus*, that some authors have declared that it is always fatal; and, while the termination will greatly depend on the character of the case to which the term is restricted, we are not prepared to admit that this statement is entirely correct. It must be admitted that those cases commonly end fatally which are followed within a few hours after the appearance of the initial symptoms with a high and increasing temperature, with an increasing stiffness of the jaw and neck, with severe muscular contractions and spasms, which are rapidly increasing in frequency, etc.; these subjects rarely survive the fourth day of illness. The mortality from tetanus, in military surgery, is very heavy. Larrey has cited twenty cases in which there were twenty deaths. After the battle of Toulouse, the English reported five cases and five deaths. Chenu reported twenty-five cases of tetanus in the British army in the Crimea, with twenty-one deaths. Macleod met with thirteen cases of this disease at Scutari, with twelve deaths, and there also are reported three hundred and forty cases of acute traumatic tetanus, in the *Medical and Surgical History of the War of the Rebellion*, with only four recoveries. It is scarcely necessary to add that many other statistical reports similar to these might be reproduced, but it does not seem to be required.

Observation apparently justifies the conclusion that tetanus is the more likely to end favorably the longer the period of time between the receipt of the traumatism and the appearance of the tetanoid symptoms. Poland has remarked on this subject, that: "The interval between the receipt of the injury and the first symptoms of tetanus is termed by some the period of acces-

sion or incubation. This varies from a few hours to many days, and must of itself depend, in a great measure, upon a variety of concomitant circumstances, which will be more appropriately considered under the predisposing causes, such as age, constitution, climate, and sex.

"It is asserted and generally maintained to be correct, that tetanus, occurring over twenty-two days after the injury has been inflicted, is more likely to be recovered from; and that the more sudden the onset after the receipt of the injury, the more surely will the result be fatal; but, at the same time, we must bear in mind that some of the severest and most rapid cases have occurred where an interval of ten days has elapsed.

. . . . .

"Previous to the 10th day .	130 cases,	of whom	101	died
From the 10th to 22d day .	126	" "	65	"
Above 22 days . . .	21	" "	8	" "[1]

It is well known that the course of this disease varies widely in different cases, instances having been recorded in which a fatal termination took place after the lapse of a few hours, while in other instances many weeks have passed before there was complete restoration. Whytt reports the death of a young girl, as having been caused by tetanus, within ten hours after the commencement of the disease. The majority of the deaths occur within the first ten days' illness. Frederick reported 128 fatal cases, in which there were 83 deaths within the first four days. Poland collected 262 fatal cases, 63 *per cent.* died during the first five days, and 88 *per cent.* during the first ten days. Bauer declares: "That after the first days the probability of recovery rapidly increases. This has long been known, and found expression in the Hippocratic aphorism, according to which tetanus ends in recovery if the fourth day of the disease can be survived. This rule is, of course, not true within such narrow limits, as death may occur, exceptionally, even after the course of weeks. These exceptions depend upon the fact, either that the paroxysms of spasms

[1] Holmes's System of Surgery, vol. i. p. 318 *et seq.* Wm. Wood & Co., N. Y., 1869.

are renewed after they had once ceased, or death takes place from exhaustion and complications. The paroxysms of spasms exert a special influence upon the extreme mortality during the first stage of the disease; their long continuance renders life impossible; and hence, if their severity does not quickly diminish, they prove fatal. In fact, death frequently occurs during an attack. In other cases the spasms cease, and death follows during a mild delirium, generally with greatly increased frequency of the pulse and high temperature. In cases of recovery the convulsive attacks diminish, becoming lighter and less frequent, and after a time entirely cease. The rigidity still continues for a while; it disappears very gradually, and not in any particular order. Hence it is generally many weeks before complete recovery; indeed, a certain irregularity of muscular action, the sense of stiffness, may persist quite a long time. Possibly ruptures and hemorrhages have an influence in this direction. The return of sleep is also a favorable indication. In certain cases of tetanus permanent consequences, paralyses, have been reported. This is, however, very rare if, indeed, the accuracy of these observations may not be doubted."[1]

TREATMENT.—The object sought to be accomplished by the treatment of tetanus is the arrest or diminution of the increased reflex power of the spinal cord. It may be necessary for the attainment of this purpose to give our attention to every part of the nervous system—including the original point of irritation in the wound—the cerebro-spinal axis; and likewise the centripetal and centrifugal conductors. The treatment is both *local* and *general*. The local treatment is directed to modifying the wound, to acting on the sensitive and motor nerves, or the immediate removal of the point of irritation. The following methods of local treatment have been frequently employed by surgeons, for the accomplishment of their object, viz., cauterization of the wound, extirpation or stretching of the nerves, as well as amputation of the limb. It is general, when, by intro-

[1] Ziemssen's Cyclopædia of the Practice of Medicine, vol. xiv. p. 357 *et seq.*, translation. Wm. Wood & Co., N. Y., 1877.

ducing certain drugs into the circulation, we seek to produce on the nervous system the effects already made known by experimental physiology. During the last fifty years there have been employed in the treatment of tetanus many new drugs; but, thus far, we have found no specific, although many lives have been unquestionably saved by our improved medication. It is true we have not reached a point in our treatment of traumatic tetanus, where we are enabled to say on the fourth day of this terrible disease, in spite of the fact that our patient is still suffering from the most aggravated form of the affection, that we will save him from death; but we believe it is quite possible, in many instances, *to so modify this morbid process as to render chronic that which would otherwise have been acute.* Furthermore, we know that the chronic cases of this disease commonly recover, while the acute cases are generally fatal. The improvement which has been attained in the management of this frightful disease is *one of the grandest achievements of rational medicine during the present age.* The careful study of its etiological and pathological conditions, as well as its *modus operandi* in the production of death—which is commonly either by exhaustion or asphyxia—*has shown us* that the *primary object of all medication is to arrest, or if this be impossible, to diminish the increased reflex nervous excitability.* Let the surgeon, therefore, strive to arrest all muscular contractions, to prevent all spasms, and to nourish the patient.

Local Treatment.—The local treatment of this disease is naturally divided into the *prophylactic*, *palliative*, and *curative*. The prophylactic treatment should commence with the removal of all foreign bodies from the wound, and the application of some non-irritating dressing. The pathological study of this disease has impressed me with the idea that it does not commonly arise from the entrance of a septic poison into the circulation; but *that it is caused by a local irritation*—which may be mechanical, chemical, or inflammatory—and which produces its frightful effects through an exaggerated reflex nervous action. If this theory is correct, it then follows that all our local treatment should be directed to the prevention of any sort of irrita-

tion in the wound. Therefore the most important question which now presents itself for our consideration is, What system of wound treatment will most effectually accomplish this object? In this respect we are fully satisfied that no system has yet been employed which is equal to the Listerian method.

It removes more effectually the various sorts of irritation from the wound than any other system which has ever been devised. The danger of irritation arising from the use of ligatures, sutures, etc., are here reduced to the minimum, while inflammatory action in the wound is almost unknown. The cotton-wadding treatment—first employed by A. Guèrin—may be unquestionably very properly applied under certain circumstances.

Baron Larrey sought to establish a healthy suppuration in the wounds of his patients who were suffering from tetanus, and believed this to be a very important curative measure. In order to accomplish this object he was in the habit of applying vesicating powder to the wound, but in this practice he has no imitators, since hot antiseptic fomentations are considered preferable. He likewise imitated the practice of the Arabian surgeons of the fifteenth century, and employed the red-hot iron to cauterize the wound, which was deeply burned, and he has reported five cases of traumatic tetanus which recovered under this treatment. Larrey attached great importance to the modification caused in the wound and in the nerve extremities by the red-hot iron and by the action of the heat in reëstablishing the suppuration. Lavergne, in 1866, proposed the use of sulphuric acid to reëstablish the suppuration. Larrey was the first to resort to the division of the nerves for the purpose of arresting the reflex nervous action in tetanus; however, this operation was not practised in France by his immediate successors. It therefore remained for Letievant, of Lyons, in modern times, to revive this operative procedure. It was thought that neurotomy would give immediate relief in these cases. In fact, one case of this kind was cited by Letievant. In 1873, one author reported sixteen cases of neurotomy with ten successes

and six failures. In some of these unsuccessful cases there had been performed four or five neurotomies, in order to sever all nervous connection between the wound and spinal cord. The principal reasons assigned in explanation of the failures attending the performance of neurotomy in tetanus, were those arising from neglect or inability to sever all nervous connection between the wound and the spinal cord; or, otherwise, in a failure on the part of the surgeon to act, until after the occurrence of pathological changes in the cord, when it becomes possible for the disease to perpetuate itself independent of the original traumatism. The results of the neurotomies which have been performed for the relief of tetanus are twenty-one operations and ten deaths. (These results are certainly too limited to possess much practical value, and the fact should not be lost sight of that the originator of any form of treatment commonly obtains better results than his followers.) The paralysis that follows this operation usually disappears within six months. Letiévant advises neurotomy in the following cases:—

1. When the tetanus is preceded or accompanied by local muscular contractions, indicating an irritable condition which radiates from the wound.

2. When, the local pain being violent, an examination by pressure over the nerves distributed to the wound, produces a distinct shock which is perceptible to the patient.

3. When an intense local pain coexists with a wound in which the nerve lesion may be located with anatomical precision.

4. When the exacerbations of local pains accompany the general spasms, characterizing a form of tetanic aura. Baron Larrey has recommended amputations in cases of tetanus for reasons similar to those which are assigned in justification of neurotomy. He adds that, "The amputation of the limb, when performed during the first moments after the appearance of the symptoms, suspends every communication of the source of the complaint with the remainder of the individual. This division unloads the vessels, causes the cessation of the nervous

twitches, and destroys the convulsive motion of the muscles."[1] Prof. Hamilton has remarked: "Nor do we hesitate to say that in case the disease has made but little progress, especially if only the muscles of the jaw are involved in the spasms, amputation will often afford a reasonable ground for hope, particularly when the amputation does not involve parts near the body, as where the wounds are situated in the fingers or toes, or even in cases of injuries of the forearm or lower portions of the leg. We are informed that in a case of trismus presented in one of the U. S. hospitals at Washington, prompt amputation of the forearm completely arrested the disease. Many similar examples have from time to time been reported by surgeons."[2]

At the time when Trnka wrote his treatise, Monro, Harrison, White, and Plenck had amputated toes. Dalaroche had proposed the amputation of the forearm, but Larrey had clearly stated the indications for this operation. He had performed three amputations for tetanus with two failures. The Paris school of medicine with Dupuytren, and the English with S. and A. Cooper, were not favorable to this method. At the present time the surgical professíon do not regard amputation with much favor in these cases; although it would seem to increase the patients' chances for life, if it could be performed at a very early stage of the disease. Verneuil, without being a partisan, regretted that he had not employed it for one of his patients. Frederick, in 1837, reported 220 cases of amputation with twenty-four recoveries. Curling, in 1836, reported seven recoveries in eleven amputations. Poland relied on the opinion of A. Cooper, and cited only two cases of amputation with one death. Yandell reported seventeen amputations with seven deaths. There were reported in Italy, in 1859, three amputations with three deaths. Kretschy and Early have each recently obtained a grand success in a desperate case. Early has carefully reported in the New York Medical Journal for August, 1874, the details of an amputation of the leg, there being a wound in the foot,

[1] Larrey on Wounds, p. 68, translation by E. F. Rivinus, M.D., published in Philadelphia, 1832.

[2] Treatise on Military Surgery, p. 599.

which was performed on the fifth day after the commencement of tetanus. The day after the operation all trace of tetanus had disappeared and in three weeks the patient was discharged. Rizzeli has recommended disarticulation at the knee in the case of tetanus produced by a wound in the foot or lower portion of the leg. Spence, on the contrary, declared that he had frequently amputated the fingers without any advantage to his patients, although the operations had been performed under favorable circumstances. The attention of the surgical profession has been quite recently withdrawn from the operative procedures, which have been previously described in connection with the treatment of tetanus, and fixed on nerve stretching in these cases.

This operation was experimentally studied in 1858 by Harlen and Haber, and afterwards by Valentin in 1864. Schleich studied carefully the sensibility of the nerves after their elongation. At this time there are a large number of monographs on this subject written in different languages, and nerve stretching is now applied to the treatment of various diseases. Consequently the physiological and practical effects of this operation, as well as the anatomical changes and functional disturbances, are now well understood. It produces on certain animals, besides an arrest of the centripetal current, some trophic disturbances. This operation having been well performed, "has but little influence over motility, and is never followed by persistent paralysis of movement, while, on the contrary, the appearance of a lasting anæsthesia is indispensable to its therapeutical action, when it is directed, as is most frequently the case, against an exaggeration of the direct or reflex sensory-motor irritability of the nerves. . . . . In *tetanus*, elongation has given several successes, attributed to Vogt, Verneuil, Clarke, Ratton (of Madras), and others, when the operation has not been done too late, and when all the nerves coming from the diseased region have been elongated."[1]

[1] The International Encyclopædia of Surgery, vol. iii. p. 629 *et seq.* Wm. Wood & Co., N. Y., 1883.

The statistics of all the published cases of tetanus treated by nerve stretching up to July, 1881, are as follows: Total number so treated, 30; recoveries, 9; deaths, 21.

General Treatment.—The general treatment of tetanus includes all necessary hygienic measures, and the administration of medicines for the purpose of ameliorating the condition of the patient by their constitutional effects. The subject of hygiene might be advantageously considered in its bearing on tetanus from a prophylactic and curative standpoint. We think it must be generally admitted, that the diminished mortality from tetanus in our modern wars, which becomes apparent to every observer, when he compares the statistics collected within the last half century with those of an earlier date, that the marked improvement has been due to better hygienic conditions. The curative hygiene is equally applicable to all cases of tetanus, whether the disease be spontaneous or traumatic, acute or chronic.

The most important of all conditions—that on which we must insist above all others—is absolute rest and complete isolation—a precaution which is too frequently neglected in sick rooms and the wards of our hospitals. The patient should be placed in a separate room moderately warmed—free from noise—in order to avoid any excitement which may produce the general spasms. It is claimed that complete recoveries have taken place under this management without medication, while other cases have been greatly relieved by it. These patients should be carefully watched, but never annoyed. Their bodily wants should be properly supplied; but this should be accomplished without either physical or mental disturbance. Some light purgative may be given to counteract the tendency to constipation ; but, even this treatment should not be repeated unless there are some indications for it. The state of the digestive organs and the circulation are improved by attention to these minor details. The patient should receive a moderate quantity of liquid food when it can be given without too much annoyance too him. The hot vapor bath, aided by sudorifics, has been sometimes advantageously employed.

The old *antiphlogistic* treatment by venesection, leeching, and

calomel—which was once much in vogue—has been practically abandoned. Poland says, when discussing the subject of constitutional treatment that: "Almost every internal remedy has been successively tried, and no one individual medicine has been singled out as an appropriate means of cure: thus antiphlogistics, including blood-letting, purgatives, calomel, antimony, colchicum, etc., have been extensively used; alteratives in the shape of the varied preparations of mercury, large doses of fixed alkalies, solutions of arsenic, etc.; diurectics, in the form of tincture of cantharides, oil or spirits of turpentine, given in frequent and large doses, so as to irritate the urinary passages or to occasion bloody urine; sedatives, such as digitalis, tobacco, nicotine, hydrocyanic acid, aconitia; anodynes and narcotics, as opium, morphia, belladonna, colchicum, cannabis Indica, ether, and chloroform internally and by inhalation; stimulants and antispasmodics, including musk, ammoniacum, camphor, turpentine, assafœtida, castor, wine, and other stimulants; tonics, such as quinine, bark, strychnia, iron, zinc, etc.; hygienics and dietetics; as support, milk-diet, etc.; tracheotomy and laryngotomy. The Calabar bean in sufficient doses to paralyze the voluntary muscles has been attended with great success, although it has, on the other hand, failed very frequently. . . . . John Hunter thus sums up his views on the treatment of tetanus: 'All the antispasmodics have been given but without apparent success; opium has kept its ground the longest, but with little reason, as it only quiets; but from some patients having got well under its use, its name has been raised; I have tried it both in large and small doses, though always unsuccessfully. I think medicines have no power without they produce some visible effect. Opium never removes the cause, though it will prevent the effects; it cures the spasms and removes pain, but it does not remove the cause. It often does good, by not allowing the symptoms to do harm to the constitution.' "[1]

[1] Holmes's System of Surgery, vol. i. p. 332 *et seq.* Wm. Wood & Co., N. Y., 1869.

The rational use of medicine in the treatment of tetanus practically requires the selection and administration of such drugs as have been found *most efficacious in subduing the exaggerated reflex nervous action;* and among these may be especially mentioned sulphate of quinine, Calabar bean, curara, and the hydrate of chloral. The sulphate of quinine was first employed in a case where it was believed that malarial poison played a certain role in the production of tetanoid symptoms, then it became an important factor in enabling the physician to differentiate between true tetanus and convulsive complications arising in connection with pernicious fevers. The observations of the physicians of Guyana showed that, in true tetanus, the sulphate of quinine lost its power, the disease developed in spite of the heroic doses, even certain complications disappeared, but the reflex contractions persisted. Coste, of Marseilles, recalling to mind the fact that he had read a report of a case which had been successfully treated with the sulphate of quinine, employed it in the treatment of his son, a lad of sixteen years; the dose was from one to two drachms, and the tetanus was cured. He obtained his second success in the treatment of tetanus with this drug in 1874, but, at London, Taylor reported four cases treated by this method with four deaths. Nevertheless the sulphate of quinine has gained some reputation, in England, through the observations of Grantham, Hutchinson, and Hayes Walton. Let us now refer to the experimental and theoretical basis on which the use of this drug seems to rest.

We will here call attention to the excellent paper by Wm. T. Sedgewick, Ph.B., Fellow of the Johns Hopkins University, Baltimore, U. S. A., entitled "*The Influence of Quinine upon the Reflex Excitability of the Spinal Cord*," who reaches the following conclusions:—

1. Quinine salts in small doses seem to depress the reflex excitability of the cord by stimulation of the vagus nerve, mainly through its endings in the heart.

2. This places the quinine action alongside other stimuli of sensory nerves, and explains its action by saying that it is a special case of reflex depression by simultaneous stimulation.

3. Goltz's theory is supported, and that of Sotschnow much weakened by these phenomena.

4. Reflex depression under quinine salts, in the pithed frog, is a case wholly different from the same depression in the entire frog. Larger doses are required, and the drug possibly acts as a direct poison on the cord."[1]

Dr. M. Foster has informed us, that: "If quinine be injected under the skin of the back of a frog the period of incubation of reflex action will be much prolonged. If, after the retardation has become clearly developed, the brain be removed, the period of incubation rapidly returns to the normal. And if the quinine is similarly injected beneath the skin of a frog from which the brain has been previously removed, no such retardation makes its appearance. From this we may infer that the injection of the quinine inhibits the reflex actions of the spinal cord by stimulating an inhibitory mechanism in the brain."[2]

Dr. Otis Frederick Manson has remarked that: "In the absence of any other satisfactory solution of the *modus operandi* of quinine, we are justified in declaring that it potently contributes to the removal of disease by rendering the nervous system insensible to the action of the morbific causes of those maladies in which its employment has been proven by experience to be efficacious. It does not, to use a hackneyed phrase, *inhibit reflex action*, for reflex action requires as its factors an afferent nerve, a sensitive centre, and an efferent conductor of a reflected impression, but it *impairs the impressibility itself*, and 'fatal things pass harmless' by the paralyzed centre. The centre does not and cannot reflect an impression which it has been rendered incapable of receiving. It has been *paralyzed partially or perfectly* by quinine, and therefore placed beyond the pale of danger. In a word, if we may be excused for coining a new term, *quinine is a* PARALYSANT. This may seem a severe and repulsive designation, as in proper quantities it merely *benumbs, stupefies*, or *narcotizes* the nervous centres, but these are really but *varying degrees of* PARESIS. The *theory*

[1] The Journal of Physiology, vol. iii. No. 1, p. 35.
[2] A Text Book of Physiology, p. 604.

here advanced, based solely on *facts*, can only lead to *safe* and *certain results* if guided by the inexorable rule in its administration, *the physician constantly has in view the end to be attained*, viz., to render the receptive centres securely insentient to its morbific assailants, and to hold them in subjection until they have lost by elimination or from exhaustion their power to impress."[1]

In concluding my remarks in regard to the action of quinine in tetanus, I can do no better than to cite the words of my learned friend, Dr. Henry F. Campbell, of Augusta, Ga., who says: "Among the apyrexic neuroses none equals in its severity, its inveteracy, and fatality, traumatic tetanus; and of all neuroses, pyrexic and apyrexic, no one presents a more typical and well-defined exhibition of reflex motory domination. Since the use of chloral, chloroform, and the bromides, this disease has come to be considered not so uniformly fatal as once it was regarded; but long previous to their application, from the observation of cases treated by what would now be regarded as enormous doses of quinine at the hands of Dr. Robert Campbell, over 1300 grains having been taken during twenty-seven days, I had been convinced, and have no reason to change my opinion, that it is by far the most reliable means for combating the symptoms, and for finally curing this perhaps by far the most unmanageable of all the morbid reflexes."[2]

CHLORAL.—O. Liebreich and Langenbeck proposed the use of chloral as a remedy for tetanus, based on the fact that this medicine produces anæsthesia with loss of voluntary and reflex movements. Verneuil, in France, lauded this treatment highly before the Surgical Society, in 1870. There should be, according to Couty, a direct modification of the nerve cells and the muscular elements. In tetanus, the chloral modifies likewise the sensibility in the wound, relaxes the contraction, and diminishes the force and frequency of the spasms. These are important points gained by the administration of this drug. The chloral

[1] A Treatise on the Physiological and Therapeutic Action of the Sulphate of Quinine, p. 161 *et seq.*

[2] Gynæcological Transactions, vol. v. 1881, reprint, p. 10.

serves to relax, for a brief period of time, the masseter and pharyngeal muscles. This is highly important, inasmuch as it enables the patient to take nourishment, and, since the condition of relaxation may exist while he is fully conscious, he is therefore entirely freed from the danger of being asphyxiated or starved. Another highly advantageous effect, arising from the free administration of this drug, is that it produces a quiet sleep with little congestion of the face and a profuse perspiration. The temperature is also slightly lowered; then during this period of sleep, which should occur soon after taking the medicine, the muscular contractions disappear, or if not entirely, at least from some of the groups. The general spasms do not occur. The patient on awakening should take another dose of chloral; thus the affection may be prolonged with comfort to both patient and physician; thus the fatal limit fixed by Hippocrates, four days, may be safely passed, the disease which would otherwise have been acute has been made chronic; and which otherwise would have been speedily fatal may now eventually end in recovery. There are, however, some cases of tetanus, in which the administration of the chloral does not prevent the pulse from becoming very frequent, or the temperature from steadily rising. In spite of the very large doses, the muscular contractions are but slightly diminished in their force or frequency, the jaws remaining fixed, and the patient unable to swallow. But in all these cases the dose should be *steadily increased until it produces sleep*. There may be given to an adult fifteen or sixteen grammes per day, and it is very rare that this quantity does not calm the muscular contractions. We claim for the chloral in the treatment of tetanus, that it is safer and more easily managed than either chloroform or ether, and consequently it should displace those agents in these cases, although it may be true that its action resembles theirs in many particulars.

In 1874, Orè, of Bordeaux, proposed and practised *intravenous injections of chloral* for the relief of tetanus. He cured one patient in this manner. The effect of the drug is promptly realized; but in most respects its remedial action is the same as though given by the mouth, but it is unquestionably a danger-

ous procedure. The injection of this drug into a vein has been followed by the formation of clots which arrested the circulation of the blood in the pulmonary artery and was promptly followed by death.

Lannelongue has reported an autopsy of an unfortunate case of this nature. Intravenous injections of chloral have since been abandoned in France. The reported results from the use of chloral in the treatment of tetanus are as follows:—

Chopard, in his thesis, under the direction of Verneuil, enumerated without classification, 132 cases, with 69 recoveries and 68 deaths.

Labbi, in 1871, cited 32 acute cases; 14 recovered and 18 died.

Beck, in 1872, found 36 cases, 21 recoveries, and 15 deaths.

Knecht, in 1878, reported 134 cases with 79 recoveries and 55 deaths.

Calabar Bean, the active principle of which was isolated by Vée, in 1864, had been employed, in 1863, by Holmes Coote, in the treatment of tetanus, at Saint Bartholomew's Hospital, in London. This medicine, it is true, was combined with morphine in the treatment of the above-mentioned case. However, the start having been made, Eben Watson, in 1865, treated four cases with the extract of the Calabar bean. He had *three successes* and in the *fourth case* there had been a marked improvement although it was not permanent. Giraldès and Bouvier, in France, employed the active principle of this drug, and succeeded with it in saving the life of a child. Germain Sée reported the second successful case treated with it in France, in 1868. Bourneville published his researches on the Calabar bean, in 1867, and two years later Navarro, in his inaugural thesis, was able to report 17 cases of tetanus treated with ésérine with twelve recoveries. Since this epoch, as was remarked by Charrière, in 1881, the ésérine has been rejected and chloral employed in its place. The most complete statistics on this subject are those prepared by Knecht, who in 1878 reported 60 cases treated with this drug, 33 recoveries and 27 deaths. Under the influence of a minimum dose of ésérine there is

muscular relaxation, the jaws are movable, the body sinks down, the head remains motionless, the contractions arrested; if, on the contrary, the poison has been absorbed in a larger quantity, there will be violent spasms, convulsive with fibrillous trembling, there is marked dyspnœa and the heart's action is irregular. The ésérine always produces a certain degree of congestion of the face, a profuse bronchial secretion, inasmuch as it embarrasses the functions of respiration, and among animals the death is commonly from syncope or asphyxia. It cannot be denied that this powerful medical agent may be a source of danger, if it is handled carelessly. The discontinuance of the use of ésérine, which we have mentioned, may have depended on the fact that we now know more of its action. In fact, that it does not arrest, as had been thought, the excito-motor power of the spinal cord, and it was, therefore, necessary to discontinue it, in favor of something else acting more favorably on the same centres as the tetanus; this alkaloid rather tends to excite the cerebro-spinal axis. However, the ésérine supplies exactly the means to suppress the dangerous effects of the excitation, inasmuch as it destroys the conductility of the motor nerves, isolating, so to speak, the whole muscular system. For these reasons the ésérine ought to be carefully watched and its absorption perfectly controlled.

CURARA was, as is known, first used in tetanus by Vella, in the Italian war of 1853, and, supported by the current theory of the relation between the muscular action and the temperature, had a warm reception, especially in Italy and France. Dr. Sayre, of New York, at the same time reported an unsuccessful case treated with this drug. Chassaignac, the following year, reported a successful case; but this report appeared in the medical journals about the same time that they chronicled Manoc's and Vulpian's report of a failure with the curara. Folin injected subcutaneously, 0.077 gr. within five hours, and lost his patient. Gintrac and Middledorpf failed also with curara. Spencer Wells had one success and two failures. Demme obtained by this treatment eight recoveries in twenty-two cases, and Busch five out of eleven by injecting the $\frac{1}{50}$ to the $\frac{1}{30}$ of a grain

within two hours; Capozzi, Morra, and Gherini each had one success with the curara treatment.

Hansen, who reports the treatment of three cases of tetanus, declares particularly, that, in two cases, the morphine succeeded better than the curara. He believes the curara increases the muscular contractions. Taylor reports three failures and one success with the curara treatment. Knecht has collected 51 cases in which curara was employed, with 26 recoveries and 25 failures. A careful study of these reports forces the conclusion that the drugs, in some of the cases, ***were either entirely inert,*** or, that the doses employed were wholly insufficient to produce any characteristic physiological action. Having, a few years since, made a series of experiments on animals, with curara, which came from five different sources—the specimens differed widely in their physical appearances; but in a still more marked degree in their intensity of action—I was constrained in concluding my paper to write as follows: "It must be apparent, that, owing to the uncertain strength of the woorara found in the drug market, it is wholly impossible to mention or even approximate a dose; and consequently the physician who intends to employ it should, if possible, first determine its relative strength by experiments on animals; or should he be compelled to use it in an emergency, then I would suggest that, in cases of rabies or traumatic tetanus, where promptness in action may save the life of the patient, the first dose be only one-sixteenth of a grain, ***but that this dose should be doubled every half hour until its full physiological action is secured*** or the patient completely relieved."

Nitrite of Amyl.—The most recent medical agent employed in the treatment of tetanus is the nitrite of amyl. Richardson cured three cases with this drug in 1864. Forbes also reports one recovery under this treatment. Schrötter reports one recovery under the combined treatment of morphia and the nitrite of amyl. Wagstaffe, on the contrary, lost an acute case of tetanus in spite of the medication with nitrite of amyl. It cannot be claimed that the value of the nitrite of amyl has yet been determined, as a remedial agent in the treatment of tetanus.

INDEX.

48

CATALOGUE No. 1.

CATALOGUE

OF

MEDICAL, DENTAL,

Pharmaceutical & Scientific Publications,

WITH A CLASSIFIED INDEX,

PUBLISHED BY

P. BLAKISTON, SON & CO.,

(SUCCESSORS TO LINDSAY & BLAKISTON)

Booksellers, Publishers and Importers of Medical and Scientific Books,

No. 1012 WALNUT STREET, PHILADELPHIA.

THE FOLLOWING CATALOGUES WILL BE SENT FREE TO ANY ADDRESS, UPON APPLICATION.

Catalogue No. 1, including all of our own publications.

A Catalogue of Books for Dental Students and Practitioners.

A Catalogue of Books on Chemistry, Pharmacy, The Microscope, Hygiene, Human Health, Sanitary Science, Technological Works, etc.

Students' Catalogue, including the "Quiz-Compends" and some of the most prominent Text-books and manuals for medical students.

A Complete Classified Catalogue (68 pages) of all Books on Medicine, Dentistry, Pharmacy and Collateral Branches. English and American.

P. Blakiston, Son & Co.'s publications may be had through Booksellers in all the principal cities of the United States and Canada, or any book will be sent, postpaid, by the publishers, upon receipt of price, or will be forwarded by express, C. O. D., upon receiving a remittance of 25 per cent. of the amount ordered, to cover express charges. Money should be remitted by postal note, money order, registered letter, or bank draft.

☞ All new books received as soon as published. Special facilities for importing books from England, Germany and France.

The Physician's Visiting List.—*See page 4.*

Liberal Discount and Imprint Circulars to the Trade.

Press Notices of Fagge's Practice.

"Those who have read Guy's Hospital Reports for the past twenty years and the many articles in the different English journals from the pen of Charles Hilton Fagge, will expect a comprehensive, carefully prepared and painstaking volume. They will not be disappointed. One cannot proceed far in the reading of this book before he is impressed with certain features of it which are very remarkable. Let him turn to almost any page at random, and he is likely to find reference made to a dozen authors of different nationalities. His memory must have been marvelous, and he was an original worker and thinker. * * * Inflammation—that prolific subject for medical and surgical text-book writers—is very fully and clearly discussed, and in such charming style as to make it very interesting. Tubercle receives much consideration. * * * Syphilis has a chapter. * * * Very exhaustive chapters on diseases of the nervous system; and the nervous diseases of the respiratory system, starting with those of the larynx, are very fully treated of. The author has adopted a very simple plan in his discussion of diseases of the lungs. * * * Phthisis receives full consideration; * * * a very complete chapter on asthma and whooping-cough. * * * Will take and hold the very front rank among works on the practice of medicine. The second volume opens with an excellent discussion of the functional affections of the heart. Then follow chapters on diseases of the alimentary canal, including intestinal entozoa. * * * Diseases of the liver get their full share of attention. * * * The discussion of jaundice, its significance, causes and treatment, is very complete and satisfactory. The author constantly shows that thorough familiarity with the literature of all the subjects of which he treats. * * * About one hundred and fifty pages are devoted to diseases of the urinary organs. We would especially direct attention to those on albuminuria and on functional disorders of the urinary organs, calculi and gravel. * * * The chapters on gout, rheumatism and allied affections cannot fail to be of interest. * * * Rickets, mollities ostium and scurvy next receive attention, and there are interesting chapters on the various forms of anæmia."

"A general and complete index to both volumes adds great value to its usefulness. One is gratified to find reference to no fewer than thirty American authors. Certainly, these two volumes make a complete work on practice, whether as a book of reference or even as a text-book. It is in style worthy of a second place only to the classical work of Sir Thomas Watson."—*New York Medical Journal.*

"A perusal of its pages shows that it is one of the most scientific and philosophical works of its kind, being, in truth, a mine of clinical and pathological facts, which are dealt with in so masterly a manner that we know not which to admire most—the patient labor and thought expended in bringing them to light, the learning and acumen that illustrate them, or the calm and judicial spirit in which they are estimated and criticised."—*London Lancet.*

"Will for all time enhance the reputation of the author as a physician, an original thinker, and a close, accurate observer."—*Dublin Journal of Medical Science.*

"It represents the labors of one of the best-known medical men of the present century; one distinguished the world over for his untiring zeal and energy in the work of enlarging medical knowledge, and whose writings upon various subjects have universally been well received."—*Nashville Journal of Medicine and Surgery.*

"One of the few large works which one would gladly have had fuller; its whole contents are of such a quality, that curtailment in any section would have been a loss. * * * Even to class it as the best work on its subject in the English tongue, the product of one brain, would but imperfectly express our estimate of it. There is an individuality breathing through every page of it, which requires perusal to understand and appreciate. * * * In every chapter the impress is perceptible of a man doing work for the love of it, and giving out what measure of knowledge he has gained and of truth he has found."—*Edinburgh Medical Journal.*

P. BLAKISTON, SON & CO., PUBLISHERS,
1012 Walnut Street, Philadelphia.

P. BLAKISTON, SON & CO.'S

Medical and Scientific Publications,

No. 1012 Walnut St., Philadelphia.

ABERCROMBIE. Medical Jurisprudence, for Medical and Legal Students and Practitioners. By John Abercrombie, M.D. 387 pages. Cloth, $2.50

ACTON. The Functions and Disorders of the Reproductive Organs in Childhood, Youth, Adult Age and Advanced Life, considered in their Physiological, Social and Moral Relations. By William Acton, M.D., M.R.C.S. Sixth Edition. 8vo. Cloth, $2.00

AITKEN. Animal Alkaloids, the Ptomaines, Leucomaines and Extractives in their Pathological Relations. A short summary of recent researches as to the origin of some diseases by or through the physiological processes going on during life. By William Aitken, M.D., F.R.S., Professor of Pathology in the Army Medical School, Netley, England. *New Edition in Press.*

ALLEN. Commercial Organic Analysis. A Treatise on the Modes of Assaying the Various Organic Chemicals and Products employed in the Arts, Manufactures, Medicine, etc., with Concise Methods for the Detection of Impurities, Adulterations, etc. Second Edition. Revised and Enlarged. By Alfred Allen, F.C.S.

Vol. I. Alcohols, Ethers, Vegetable Acids, Starch and its Isomers. etc. $4.50

Vol. II. Fixed Oils and Fats, Hydrocarbons and Mineral Oils, Phenols and their Derivatives, Coloring Matters, etc. $5.00

Vol. III.—Part I. Cyanogen Compounds, Alkaloids, Animal Products, etc. *Nearly ready.*

ALLINGHAM. Diseases of the Rectum. Fistula, Hæmorrhoids, Painful Ulcer, Stricture, Prolapsus, and other Diseases of the Rectum, their Diagnosis and Treatment. By William Allingham, F.R.C.S. Fourth Edition, Enlarged. Illustrated. 8vo. Paper covers, .75; Cloth, $1.25

ALTHAUS. Medical Electricity. Theoretical and Practical. Its Use in the Treatment of Paralysis, Neuralgia, and other Diseases. By Julius Althaus, M.D. Third Edition, Enlarged. 246 Illustrations. 8vo. Cloth, $6.00

ANDERSON. A Treatise on Skin Diseases. With special reference to Diagnosis and Treatment, and including an Analysis of 11,000 consecutive cases. By T. McCall Anderson, M.D., Professor of Clinical Medicine, University of Glasgow. With several Full-page Plates, two of which are Colored Lithographs, and numerous Wood Engravings. Octavo. 650 pages. Cloth, $4.50; Leather, $5.50

ARLT. Diseases of the Eye. Clinical Studies on Diseases of the Eye. Including the Conjunctiva, Cornea and Sclerotic, Iris and Ciliary Body. By Dr. Ferd. Ritter von Arlt, University of Vienna. Authorized Translation by Lyman Ware, M.D., Surgeon to the Illinois Charitable Eye and Ear Infirmary, Chicago. Illustrated. 8vo. Cloth, $2.50

BAR. Antiseptic Midwifery. The Principles of Antiseptic Methods Applied to Obstetric Practice. By Dr. Paul Bar, Obstetrician to, formerly Interne in, the Maternity Hospital, Paris. Authorized Translation by Henry D. Fry, M.D., with an Appendix by the author. Octavo. Cloth, 1.75

BARNES. Lectures on Obstetric Operations, including the Treatment of Hemorrhage, and forming a Guide to Difficult Labor. By ROBERT BARNES, M.D., F.R.C.P. Fourth Edition. Illustrated. 8vo. Cloth, $3.75

BARRETT. Dental Surgery for General Practitioners and Students of Medicine and Dentistry. Extraction of Teeth, etc. By A. W. BARRETT, M.D. Illustrated. *Practical Series.* [*See page 19.*] Cloth, $1.00

BARTLEY. Medical Chemistry. A Text-book for Medical and Pharmaceutical Students. By E. H. BARTLEY, M.D., Professor of Chemistry and Toxicology at the Long Island College Hospital; President of the American Society of Public Analysts; Chief Chemist, Board of Health, of Brooklyn, N. Y. With Illustrations, Glossary and Complete Index. 12mo. Cloth, $2.50

BEALE. On Slight Ailments; their Nature and Treatment. By LIONEL S. BEALE, M.D., F.R.S., Professor of Practice, King's Medical College, London. Second Edition. Enlarged and Illustrated. Paper covers, .75; Cloth, $1.25

Urinary and Renal Diseases and Calculous Disorders. Hints on Diagnosis and Treatment. Demi-8vo. 356 pages. Cloth, $1.75

The Use of the Microscope in Practical Medicine. For Students and Practitioners, with full directions for examining the various secretions, etc., in the Microscope. Fourth Edition. 500 Illustrations. 8vo. Cloth, $7.50

How to Work with the Microscope. A Complete Manual of Microscopical Manipulation, containing a full description of many new processes of investigation, with directions for examining objects under the highest powers, and for taking photographs of microscopic objects. Fifth Edition. Containing over 400 Illustrations, many of them colored. 8vo. Cloth, $7.50

Bioplasm. A Contribution to the Physiology of Life, or an Introduction to the Study of Physiology and Medicine, for Students. With numerous Illustrations. Cloth, $2.25

Life Theories and Religious Thought. Six Colored Plates. Cloth, $2.00

On Life and Vital Action in Health and Disease. 12mo. Cloth, $2.00

One Hundred Urinary Deposits, on eight sheets, for the Hospital, Laboratory, or Surgery. New Edition. 4to. Paper, $2.00

BEASLEY'S Book of Prescriptions. Containing over 3100 Prescriptions, collected from the Practice of the most Eminent Physicians and Surgeons—English, French and American; a Compendious History of the Materia Medica, Lists of the Doses of all Officinal and Established Preparations, and an Index of Diseases and their Remedies. By HENRY BEASLEY. Sixth Edition. Revised and Enlarged. Cloth, $2.25

Druggists' General Receipt Book. Comprising a copious Veterinary Formulary; Recipes in Patent and Proprietary Medicines, Druggists' Nostrums, etc.; Perfumery and Cosmetics; Beverages, Dietetic Articles and Condiments; Trade Chemicals, Scientific Processes, and an Appendix of Useful Tables. Ninth Edition. Revised. Cloth, $2.25

Pocket Formulary and Synopsis of the British and Foreign Pharmacopœias. Comprising Standard and Approved Formulæ for the Preparations and Compounds Employed in Medical Practice. Eleventh Edition. Cloth, $2.25

BENTLEY AND TRIMEN'S Medicinal Plants. A New Illustrated Work, containing full botanical descriptions, with an account of the properties and uses of the principal plants employed in medicine, especial attention being paid to those which are officinal in the British and United States Pharmacopœias. The plants which supply food and substances required by the sick and convalescent are also included. By R. BENTLEY, F.R.S., Professor of Botany, King's College, London, and H. TRIMEN, M.B., F.H.S., Department of Botany, British Museum. Each species illustrated by a colored plate drawn from nature. In forty-two parts. Eight colored plates in each part.

Price reduced to $1.50 per part, or the complete work handsomely bound in 4 volumes. Half Morocco, Gilt, $75.00.

BIBLE HYGIENE; or Health Hints. By a physician. Written to impart in a popular and condensed form the elements of Hygiene; showing how varied and important are the Health Hints contained in the Bible, and to prove that the secondary tendency of modern Philosophy runs in a parallel direction with the primary light of the Bible. 12mo. Cloth, $1.00

BIDDLE'S Materia Medica and Therapeutics. Eleventh Edition. For the Use of Students and Physicians. By Prof. JOHN B. BIDDLE, M.D., Professor of Materia Medica in Jefferson Medical College, Philadelphia. The Eleventh Edition, thoroughly revised, and in many parts rewritten, by his son, CLEMENT BIDDLE, M.D., Assistant Surgeon, U. S. Navy, and HENRY MORRIS, M.D., Demonstrator of Obstetrics in Jefferson Medical College, Fellow of the College of Physicians, of Philadelphia, etc. The Botanical portions have been curtailed or left out, and the other sections, on Therapeutics and the Physiological action of Drugs, greatly enlarged. Cloth, $4.00; Sheep, $4.75

BLACK. Micro-Organisms. The Formation of Poisons by Micro-Organisms. A Biological study of the Germ Theory of Disease. By G. V. BLACK, M.D., D.D.S. Cloth, $1.50

BLODGETT'S Dental Pathology. By ALBERT N. BLODGETT. 12mo. Cloth, $1.75

BLOXAM. Chemistry, Inorganic and Organic. With Experiments. By CHARLES L. BLOXAM, Professor of Chemistry in King's College, London, and in the Department for Artillery Studies, Woolwich. Sixth Edition. Revised and Enlarged by 100 pages. With 300 Engravings. 8vo. Cloth, $4.50; Leather, $5.50

Laboratory Teaching. Progressive Exercises in Practical Chemistry. Intended for use in the Chemical Laboratory, by those who are commencing the study of Practical Chemistry. 4th Edition. 89 Illus. Cloth, $1.75

BOWLBY. Surgical Pathology and Morbid Anatomy. By ANTHONY A. BOWLBY, F.R.C.S., Surgical Register and Demonstrator of Surgical Pathology to St. Bartholomew's Hospital, etc. 135 Illustrations. Cloth, $2.00

BOWMAN. Practical Chemistry, including analysis, with about 100 Illustrations. By Prof. JOHN E. BOWMAN. Eighth English Edition. Revised by Prof. BLOXAM, Professor of Chemistry, King's College, London. Cloth, $2.00

BRUBAKER. Physiology. A Compend of Physiology, specially adapted for the use of Students and Physicians. By A. P. BRUBAKER, M.D., Demonstrator of Physiology at Jefferson Medical College, Prof. of Physiology, Penn'a College of Dental Surgery, Philadelphia. Fourth Edition. Revised, Enlarged and Illustrated. *No. 4, ? Quiz-Compend Series ?* 12mo. Cloth, $1.00
Interleaved for the addition of notes, $1.25

BRUEN. Physical Diagnosis. For Physicians and Students. By EDWARD T. BRUEN, M.D., Asst. Professor of Physical Diagnosis in the University of Pennsylvania. Illustrated by Original Wood Engravings. 12mo. 2d Ed. Cloth, $1.50

BUCKNILL AND TUKE'S Manual of Psychological Medicine: containing the Lunacy Laws, the Nosology, Ætiology, Statistics, Description, Diagnosis, Pathology (including morbid Histology) and Treatment of Insanity. By JOHN CHARLES BUCKNILL, M.D., F.R.S., and DANIEL HACK TUKE, M.D., F.R.C.P. Fourth Edition, much enlarged, with twelve lithographic and numerous other illustrations. 8vo. Cloth, $8.00

BULKLEY. The Skin in Health and Disease. By L. DUNCAN BULKLEY, M.D., Attending Physician at the New York Hospital. Illustrated. Cloth, .50

BUXTON. On Anæsthetics. A Manual. By DUDLEY WILMOT BUXTON, M.R.C.S., M.R.C.P., Asst. to Prof. of Med., and Administrator of Anæsthetics, University College Hospital, London. *Practical Series.* [*See page 19.*] $1.25

BURNETT. Hearing, and How to Keep It. By CHAS. H. BURNETT, M.D., Prof. of Diseases of the Ear, at the Philadelphia Polyclinic. Illustrated. Cloth, .50

FENWICK'S Outlines of Practice of Medicine. With Formulæ and Illustrations. By SAMUEL FENWICK, M.D. 12mo. Cloth, $1.25

FLAGG'S Plastics and Plastic Filling; As Pertaining to the Filling of all Cavities of Decay in Teeth below Medium in Structure, and to Difficult and Inaccessible Cavities in Teeth of all Grades of Structure. By J. FOSTER FLAGG, D.D.S., Professor in the Philadelphia Dental College. 8vo. *New Edition Preparing.*

FLOWER'S Diagrams of the Nerves of the Human Body. Exhibiting their Origin, Divisions and Connections, with their Distribution to the various Regions of the Cutaneous Surface, and to all the Muscles. By WILLIAM H. FLOWER, F.R.C.S., F.R.S., Hunterian Professor of Comparative Anatomy, and Conservator of the Museum of the Royal College of Surgeons. Third Edition, thoroughly revised. With six Large Folio Maps or Diagrams. 4to. Cloth, $3.50

FLÜCKIGER. The Cinchona Barks Pharmacognostically Considered. By Professor FRIEDRICH FLÜCKIGER, of Strasburg. Translated by FREDERICK B. POWER, PH.D., Professor of Materia Medica and Pharmacy, University of Wisconsin. With 8 Lithographic Plates. Royal octavo. Cloth, $1.50

FOTHERGILL. On the Heart and Its Diseases. With Their Treatment. Including the Gouty Heart. By J. MILNER FOTHERGILL, M.D., Member of the Royal College of Physicians of London. 2d Ed. Rewritten. 8vo. Cloth, $3.50

FOX. Water, Air and Food. Sanitary Examinations of Water, Air and Food. By CORNELIUS B. FOX, M.D. 110 Engravings. 2d Ed., Revised. Cloth, $4.00

FOX AND GOULD. Compend on Diseases of the Eye and Refraction, including Treatment and Surgery. By L. WEBSTER FOX, M.D., Chief Clinical Assistant, Ophthalmological Department, Jefferson Medical College Hospital; Ophthalmic Surgeon, Germantown Hospital, Philadelphia; late Clinical Assistant at Moorfields, London, England, etc., and GEO. M. GOULD, M.D. Second Edition. Enlarged. 71 Illustrations and 39 Formulæ. *Being No. 8, ? Quiz-Compend ? Series.* Cloth, $1.00. Interleaved for the addition of notes, $1.25

FRANKLAND'S Water Analysis. For Sanitary Purposes, with Hints for the Interpretation of Results. By E. FRANKLAND, M.D., F.R.S. Illustrated. 12mo. Cloth, $1.00

GALABIN'S Midwifery. A Manual for Students and Practitioners. By A. LEWIS GALABIN, M.D., F.R.C.P., Obstetric Physician to Guy's Hospital, London, and Professor of Midwifery in the same institution. 227 Illustrations. Cloth, $3.00; Leather, $3.50

GLISAN'S Modern Midwifery. A Text-book. By RODNEY GLISAN, M.D., Emeritus Professor of Midwifery and Diseases of Women and Children in Willamette Univ., Portland, Oregon. 129 Illus. 8vo. 2d Edition. Cloth, $3.00

GIBBES'S Practical Histology and Pathology. By HENEAGE GIBBES, M.B. 12mo. Third Edition. Cloth, $1.75

GILLIAM'S Pathology. The Essentials of Pathology; a Handbook for Students. By D. TOD GILLIAM, M.D., Professor of Physiology, Starling Medical College, Columbus, O. With 47 Illustrations. 12mo. Cloth, $2.00

GODLEE. Sixteen Selected Colored Plates from Godlee's Atlas of Anatomy, showing Complete Dissections of the Head and Neck. $3.00

GOODHART and STARR'S Diseases of Children. The Student's Guide to the Diseases of Children. By J. F. GOODHART, M.D., F.R.C.P., Physician to Evelina Hospital for Children, Demonstrator of Morbid Anatomy at Guy's Hospital. Edited, with notes and additions, by LOUIS STARR, M.D., Clinical Professor of Diseases of Children in the University of Pennsylvania. Cloth, $3.00; Leather, $3.50

GORGAS'S Dental Medicine. A Manual of Materia Medica and Therapeutics. By FERDINAND J. S. GORGAS, M.D., D.D.S., Professor of the Principles of Dental Science, Dental Surgery and Dental Mechanism in the Dental Department of the University of Maryland. Second Edition. Enlarged. 8vo. Cloth, $3.25

GOWERS, Manual of Diseases of the Nervous System. A Complete Text-book. By WILLIAM R. GOWERS, M.D., Prof. Clinical Medicine, University College, London. Physician to National Hospital for the Paralyzed and Epileptic. Comprising over 341 Illustrations and 1360 pages. Octavo.
Cloth, $6.50; Leather, $7.50

This work is published in two volumes in London. By special arrangements with the author, we have reprinted it in one, using the original illustrations. DR. GOWERS has taken advantage of this printing to correct a number of errors in the first volume and to add some new matter.

Diagnosis of Diseases of the Brain. 8vo. Second Edition. Illustrated.
Cloth, $2.00

GROSS'S Biography of John Hunter. John Hunter and His Pupils. By S. D. GROSS, M.D., Professor of Surgery in Jefferson Medical College, Philadelphia. With a Portrait. 8vo. Paper, .75; Cloth, $1.25

GREENHOW. Addison's Disease. Illustrated by Plates and Reports of Cases. By E. HEADLAM GREENHOW, M.D. 8vo. Cloth, $3.00

Chronic Bronchitis, especially as connected with Gout, Emphysema, and Diseases of the Heart. By E. HEADLAM GREENHOW, M.D. 12mo.
Paper, .75; Cloth, $1.25

GROVES AND THORP. Chemical Technology. A new and Complete Work. The Application of Chemistry to the Arts and Manufactures. Edited by CHARLES E. GROVES, F.R.S., and WM. THORP, B.Sc., F.I.C. In about eight volumes, with numerous illustrations. *Each volume sold separately.*

Vol. I. FUEL. By Dr. E. J. MILLS, F.R.S., Professor of Chemistry, Anderson College, Glasgow; and Mr. F. J. ROWAN, assisted by an American expert.
Nearly Ready.

HABERSHON. On Some Diseases of the Liver. By S. O. HABERSHON, M.D., F.R.C.P., late Senior Physician to Guy's Hospital. A New Edition. Cloth, $1.50

HADDON'S Embryology. An Introduction to the Study of Embryology. For the Use of Students. By A. C. HADDON, M.A., Prof. of Zoölogy, Royal College of Science, Dublin. 190 Illustrations. Cloth, 6.00

HALE. On the Management of Children in Health and Disease. A Book for Mothers. By AMIE M. HALE, M.D. New Enlarged Edition. 12mo. Cloth, .75

HARE. Tobacco, Its Physiological and Pathological Effects. Paper Covers, .50

HARLAN. Eyesight, and How to Care for It. By GEORGE C. HARLAN, M.D., Prof. of Diseases of the Eye, Philadelphia Polyclinic. Illustrated. Cloth, .50

HARLEY. Diseases of the Liver, With or Without Jaundice. Diagnosis and Treatment. By GEORGE HARLEY, M.D. With Colored Plates and Numerous Illustrations. 8vo. Price reduced. Cloth, $3.00; Leather, $4.00

HARRIS. On the Chest. With 55 Illustrations. Cloth, $2.50

HARRIS'S Principles and Practice of Dentistry. Including Anatomy, Physiology, Pathology, Therapeutics, Dental Surgery and Mechanism. By CHAPIN A. HARRIS, M.D., D.D.S., late President of the Baltimore Dental College, author of "Dictionary of Medical Terminology and Dental Surgery." Twelfth Edition. Revised and Edited by FERDINAND J. S. GORGAS, A.M., M.D., D.D.S., author of "Dental Medicine;" Professor of the Principles of Dental Science, Dental Surgery and Dental Mechanism in the University of Maryland. Two Full-page Plates and 900 Illustrations. 1100 pages. 8vo. Cloth, $6.50; Leather, $7.50

Medical and Dental Dictionary. A Dictionary of Medical Terminology, Dental Surgery, and the Collateral Sciences. Fourth Edition, carefully Revised and Enlarged. By FERDINAND J. S. GORGAS, M.D., D.D.S., Prof. of Dental Surgery in the Baltimore College. 8vo. Cloth, $6.50; Leather, $7.50

HARTRIDGE. Refraction. The Refraction of the Eye. A Manual for Students. By GUSTAVUS HARTRIDGE, F.R.C.S., Consulting Ophthalmic Surgeon to St. Bartholomew's Hospital; Ass't Surgeon to the Royal Westminster Ophthalmic Hospital, etc. 96 Illustrations and Test Types. Third Edition. Cloth, $2.00

HARTSHORNE. Our Homes. Their Situation, Construction, Drainage, etc. By HENRY HARTSHORNE, M.D. Illustrated. Cloth, .50

HEADLAND'S Action of Medicines. On the Action of Medicines in the System. By F. W. HEADLAND, M.D. Ninth American Edition. 8vo. Cloth, $3.00

HEATH'S Operative Surgery. A Course of Operative Surgery, consisting of a Series of Plates, Drawn from Nature by M. Léveillé, of Paris. With Descriptive Text of Each Operation. By CHRISTOPHER HEATH, F.R.C.S., Holme Professor of Clinical Surgery in University College, London. Quarto. Second Edition. Revised. *Sold by Subscription.* Cloth, $12.00

Minor Surgery and Bandaging. Eighth Edition. Revised and Enlarged. With 142 Illustrations. 12mo. Cloth, $2.00

Practical Anatomy. A Manual of Dissections. Seventh London Edition. 24 Colored Plates, and nearly 300 other Illustrations. Cloth, $5.00

Injuries and Diseases of the Jaws. Third Edition. Revised, with over 150 Illustrations. 8vo. Cloth, $4.50

Lectures on Certain Diseases of the Jaws, delivered at the Royal College of Surgeons of England, 1887. 64 Illustrations. 8vo. Boards, $1.00

HENRY. Anæmia. A Practical Treatise. By FRED'K P. HENRY, M.D., Prof. Clinical Med. Phila. Polyclinic, Physician to Episcopal and Phila. Hospitals, to Home for Consumptives, etc. 12mo. Half Cloth, .75

HIGGENS' Ophthalmic Practice. A Manual for Students and Practitioners. By CHARLES HIGGENS, F.R.C.S. Ophthalmic Surgeon at Guy's Hospital. *Practical Series. See Page 19.* Cloth, $1.75

Ophthalmic Practice. A Handbook. Second Edition. 32mo. Cloth, .50

HILLIER. Diseases of Children. A Clinical Treatise. By THOMAS HILLIER, M.D. 8vo. Cloth, $1.25

HILL AND COOPER. Venereal Diseases. The Student's Manual of Venereal Diseases, being a concise description of those Affections and their Treatment. By BERKELEY HILL, M.D., Professor of Clinical Surgery, University College, and ARTHUR COOPER, M.D., Late House Surgeon to the Lock Hospital, London. 4th Edition. 12mo. Cloth, $1.00

HODGE on Fœticide, or Criminal Abortion. By HUGH L. HODGE, M.D. Paper, .30

HODGE'S Note-book for Cases of Ovarian Tumors. Paper, .50

HOLDEN'S Anatomy. A Manual of the Dissections of the Human Body. By LUTHER HOLDEN, F.R.C.S. Fifth Edition. Carefully Revised and Enlarged. Specially concerning the Anatomy of the Nervous System, Organs of Special Sense, etc. By JOHN LANGTON, F.R.C.S., Surgeon to, and Lecturer on Anatomy at, St. Bartholomew's Hospital. 208 Illustrations. 8vo.
Oilcloth Covers, for the Dissecting Room, $4.50; Cloth, $5.00; Leather, $6.00

Human Osteology. Comprising a Description of the Bones, with Colored Delineations of the Attachments of the Muscles. The General and Microscopical Structure of Bone and its Development. Carefully Revised. By the Author and Prof. STEWART, of the Royal College of Surgeons' Museum. With Lithographic Plates and Numerous Illustrations. 7th Ed. Cloth, $6.00

Landmarks. Medical and Surgical. 4th. Edition. 8vo. Cloth, $1.25

HOLDEN. The Sphygmograph. Its Physiological and Pathological Indications. By EDGAR HOLDEN, M.D. Illustrated. 8vo. Cloth, $2.00

HOLLAND. The Urine and the Common Poisons. Memoranda, Chemical and Microscopical, for Laboratory Use. By J. W. HOLLAND, M.D., Professor of Medical Chemistry and Toxicology in Jefferson Medical College, of Philadelphia. Second Edition. Revised. Illustrated. Cloth, .75

HOOD. Lectures to Nurses on the Symptoms of Disease. By DONALD HOOD, M.D., M.R.C.P., Physician to the West London Hospital, etc. 12mo. Cloth, $1.00

HORWITZ'S Compend of Surgery, including Minor Surgery, Amputations, Fractures, Dislocations, Surgical Diseases, and the Latest Antiseptic Rules, etc., with Differential Diagnosis and Treatment. By ORVILLE HORWITZ, B.S., M.D., Demonstrator of Anatomy, Jefferson Medical College; Chief, Out-Patient Surgical Department, Jefferson Medical College Hospital. Third Edition. Very much Enlarged and Rearranged. 91 Illustrations and 77 Formulæ. 12mo. *No. 9 ? Quiz-Compend ? Series.* Cloth, $1.00. Interleaved for the addition of notes, $1.25

HUFELAND. Long Life. Art of Prolonging Life. By C. W. HUFELAND. Edited by ERASMUS WILSON, M.D. 12mo. Cloth, $1.00

HUGHES. Compend of the Practice of Medicine. Third Edition. Revised and Enlarged. By DANIEL E. HUGHES, M.D., Demonstrator of Clinical Medicine at Jefferson Medical College, Philadelphia. In two parts. *Being Nos. 2 and 3, ? Quiz-Compend ? Series.*

PART I.—Continued, Eruptive and Periodical Fevers, Diseases of the Stomach, Intestines, Peritoneum, Biliary Passages, Liver, Kidneys, etc., and General Diseases, etc.

PART II.—Diseases of the Respiratory System, Circulatory System and Nervous System; Diseases of the Blood, etc.

Price of each Part, in Cloth, $1.00; interleaved for the addition of Notes, $1.25

Physicians' Edition.—In one volume, including the above two parts, a section on Skin Diseases, and an index. *Revised Edition. 408 pages.* Full Morocco, Gilt Edge, $2.50

JACOBSON. Operations of Surgery. By W. H. A. JACOBSON, B.A. OXON., F.R.C.S., Eng.; Ass't Surgeon, Guy's Hospital; Surgeon at Royal Hospital for Children and Women, etc. With over 200 Illustrations. *In Press.*

JAMES on Sore Throat. Its Nature, Varieties and Treatment, including its Connection with other Diseases. By PROSSER JAMES, M.D. Fourth Edition, Revised and Enlarged. Colored Plates and Wood-cuts. Paper .75; Cloth, $1.25

JONES' Aural Surgery. A Practical Handbook on Aural Surgery. By H. MACNAUGHTON JONES, M.D., Surgeon to the Cork Ophthalmic and Aural Hospital. Illustrated. Second Edition, with new Wood Engravings. 12mo. Cloth, $2.75

JOURNAL of Laryngology and Rhinology. A Monthly Analytical Record, devoted to Diseases of the Throat and Nose. Edited by MORELL MACKENZIE, M.D. *Sample Nos., 25 cents.* Subscription per annum, $3.00

KANE'S Drugs that Enslave. The Opium, Morphine, Chloral, and Similar Habits. By H. H. KANE, M.D. With Illustrations. Cloth, $1.25

KEATING & EDWARDS. Diseases of the Heart in Children. The Diseases of the Heart and Circulation in Infancy and Adolescence. By JOHN M. KEATING, M.D., Obstetrician to the Philadelphia Hospital, etc., and WM. A. EDWARDS, Instructor in Clinical Medicine, Univ. of Penna., Physician to St. Joseph's Hospital, etc. Illustrated by Photographs and Wood Engravings. 8vo. Cloth, $1.50

KERR. Inebriety. Its Etiology, Pathology, Treatment, etc., in its various forms. By N. S. KERR, M.D., Mem. of the Council of Univ. of Glasgow. $3.00

KIDD'S Laws of Therapeutics; or, the Science and Art of Medicine. By JOSEPH KIDD, M.D. 12mo. Paper, .75; Cloth, $1.25

KIRKES' Physiology. A Handbook of Physiology. By KIRKES. Twelfth London Edition, Revised and Enlarged. By W. MORRANT BAKER, M.D. 460 Illustrations. Cloth, $4.00; Leather, $5.00

LANDIS' Compend of Obstetrics; especially adapted to the Use of Students and Physicians. By HENRY G. LANDIS, M.D., Professor of Obstetrics and Diseases of Women, in Starling Medical College, Columbus, Ohio. Third Edition. Revised. With New Illustrations. *No. 5 ? Quiz-Compend ? Series.*
Cloth, $1.00; interleaved for the addition of Notes, $1.25

LANDOIS. A Text-Book of Human Physiology; including Histology and Microscopical Anatomy, with special reference to the requirements of Practical Medicine. By DR. L. LANDOIS, Professor of Physiology and Director of the Physiological Institute in the University of Greifswald. Second American, translated from the Fifth German Edition, with additions, by WM. STIRLING, M.D., D.SC., Professor of the Institutes of Medicine in the University of Aberdeen. With 583 Illustrations. 8vo. 1 Volume. Cloth, $6.50; Leather, $7.50

LEBER AND ROTTENSTEIN. Dental Caries and Its Causes. An Investigation into the Influence of Fungi in the Destruction of the Teeth. By Drs. LEBER and ROTTENSTEIN. Illustrated. Paper, .75; Cloth, $1.25

LEE. The Microtomist's Vade Mecum. By ARTHUR BOLLES LEE. A Handbook of the Methods of Microscopical Anatomy. 660 Formulæ, etc. Cloth, $3.00

LEFFMANN'S Compend of Chemistry, Inorganic and Organic. Including Urine Analysis and the Analysis of Water. By HENRY LEFFMANN, M.D., Prof. of Chemistry and Metallurgy in the Penna. College of Dental Surgery, and in the Wagner Free Institute of Science, Philadelphia. *No. 10 ?Quiz-Compend? Series.* Second Edition. Rewritten and Adapted for Students of Medicine and Dentistry. 12mo. Cloth, $1.00. Interleaved for the addition of Notes, $1.25

LEGG on the Urine. Practical Guide to the Examination of the Urine, for Practitioner and Student. By J. WICKHAM LEGG, M.D. Sixth Edition, Enlarged. Illustrated. 12mo. Cloth, .75

LEWERS. On the Diseases of Women. With over 120 Engravings. *Practical Series. See Page 19.* 12mo. Cloth, $2.25

LEWIN on Syphilis. The Treatment of Syphilis. By Dr. GEORGE LEWIN, of Berlin. Translated by CARL PROEGLER, M.D., and E. H. GALE, M.D., Surgeons U. S. Army. Illustrated. 12mo. Paper, .75; Cloth, $1.25

LIEBREICH'S Atlas of Ophthalmoscopy, composed of 12 Chromo-Lithographic Plates (containing 59 Figures), with Text. Translated by H. R. SWANZY, M.D Third Edition. 4to. Boards, $15.00

LINCOLN. School and Industrial Hygiene. By D. F. LINCOLN, M.D. Cloth, .50

LONGLEY'S Pocket Medical Dictionary for Students and Physicians. Giving the Correct Definition and Pronunciation of all Words and Terms in General Use in Medicine and the Collateral Sciences, with an Appendix, containing Poisons and their Antidotes, Abbreviations Used in Prescriptions, and a Metric Scale of Doses. By ELIAS LONGLEY. Cloth, $1.00; Tucks and Pocket, $1.25

LIZARS. On Tobacco. The Use and Abuse of Tobacco. By JOHN LIZARS, M.D. 12mo. Cloth, .50

LÜCKES. Hospital Sisters and their Duties. By EVA C. E. LÜCKES, Matron to the London Hospital; Author of "Lectures on Nursing." 12mo. Cloth, $1.00

MAC MUNN. On the Spectroscope in Medicine. By CHAS. A. MAC MUNN, M.D. With 3 Chromo-lithographic Plates of Physiological and Pathological Spectra, and 13 Wood Cuts. 8vo. Cloth, $3.00

MACNAMARA. On the Eye. A Manual of the Diseases of the Eye. By C. MACNAMARA, M.D. Fourth Edition, Carefully Revised; with Additions and Numerous Colored Plates, Diagrams of Eye, Wood-cuts, and Test Types. Demi 8vo. Cloth, $4.00

MACDONALD'S Microscopical Examinations of Water and Air. A Guide to the Microscopical Examination of Drinking Water, with an Appendix on the Microscopical Examination of Air. By J. D. MACDONALD, M.D. With 25 Lithographic Plates, Reference Tables, etc. Second Ed., Revised. 8vo. Cloth, $2.75

MACKENZIE on the Throat and Nose. Complete in one octavo vol. Including the Pharynx, Larynx, Trachea, Œsophagus, Nasal Cavities, etc., etc. By MORELL MACKENZIE, M.D., Senior Physician to the Hospital for Diseases of the Chest and Throat, Lecturer on Diseases of the Throat at London Hospital Medical College, etc. Revised and Edited by D. BRYSON DELAVAN, M.D., Prof. of Laryngology and Rhinology in the New York Polyclinic; Chief of Clinic, Department of Diseases of the Throat, Col. of Physicians and Surgeons, New York; Sec. of the American Laryngological Association, etc. One vol. Octavo. About 800 pages. Useful Formulæ, and over 200 Illustrations. *Nearly Ready.*

The Œsophagus, Nose, Naso-Pharynx, etc. Illustrated. Being Vol. II of the First Edition of Dr. MACKENZIE'S Treatise. Complete in itself Cloth, $3.00; Leather, $4.00

The Pharmacopœia of the Hospital for Diseases of the Throat and Nose. Fourth Edition, Enlarged, Containing 250 Formulæ, with Directions for their Preparation and Use. 16mo. Cloth, $1.25

Growths in the Larynx. Their History, Causes, Symptoms, etc. With Reports and Analysis of one Hundred Cases. With Colored and other Illustrations. 8vo. Paper, .75; Cloth, $1.25

MANN'S Manual of Psychological Medicine and Allied Nervous Diseases. Their Diagnosis, Pathology, Prognosis and Treatment, including their Medico-Legal Aspects; with chapter on Expert Testimony, and an abstract of the laws relating to the Insane in all the States of the Union. By EDWARD C. MANN, M.D., member of the New York County Medical Society. With Illustrations of Typical Faces of the Insane, Handwriting of the Insane, and Micro-photographic Sections of the Brain and Spinal Cord. Octavo. Cloth, $5.00; Leather $6.00

MARSHALL & SMITH. On the Urine. The Chemical Analysis of the Urine. By JOHN MARSHALL, M.D., and Prof. EDGAR F. SMITH, of the Chemical Laboratories, University of Pennsylvania. Phototype Plates. 12mo. Cloth, $1.00

MARTIN'S Microscopic Mounting. A Manual. With Notes on the Collection and Examination of Objects. 150 Illustrations. By JOHN H. MARTIN. Second Edition, Enlarged. 8vo. Cloth, $2.75

MASON'S Compend of Electricity, and its Medical and Surgical Uses. By CHARLES F. MASON, M.D., Assistant Surgeon U. S. Army. With an Introduction by CHARLES H. MAY, M.D., Instructor in the New York Polyclinic. Numerous Illustrations. 12mo. *Being Medical Briefs, No.* 3. Cloth, $1.00

MAYS' Therapeutic Forces; or, The Action of Medicine in the Light of the Doctrine of Conservation of Force. By THOMAS J. MAYS, M.D. Cloth, $1.25

Theine in the Treatment of Neuralgia. Being a Contribution to the Therapeutics of Pain. 16mo. ½ bound. .50

MEADOWS' Obstetrics. A Text-Book of Midwifery. Including the Signs and Symptoms of Pregnancy, Obstetric Operations, Diseases of the Puerperal State, etc. By ALFRED MEADOWS, M.D. Third American, from Fourth London Edition. Revised and Enlarged. With 145 Illustrations. 8vo. Cloth, $2.00

MEDICAL Directory of Philadelphia, Pennsylvania, Delaware and Southern half of New Jersey, containing lists of Physicians *of all Schools of Practice*, Dentists, Druggists and Chemists, with information concerning Medical Societies, Colleges and Associations, Hospitals, Asylums, Charities, etc. Morocco, Gilt edges, $2.50

MEIGS. Milk Analysis and Infant Feeding. A Practical Treatise on the Examination of Human and Cows' Milk, Cream, Condensed Milk, etc., and Directions as to the Diet of Young Infants. By ARTHUR V. MEIGS, M.D., Physician to the Pennsylvania Hospital, Philadelphia. 12mo. Cloth, $1.00

MEIGS and PEPPER on Children. A Practical Treatise on the Diseases of Children. By J. FORSYTH MEIGS, M.D., Fellow of the College of Physicians of Philadelphia, etc., etc., and WILLIAM PEPPER, M.D., Professor of the Principles and Practice of Medicine in the Medical Department, University of Pennsylvania. Seventh Edition. Cloth, $5.00; Leather, $6.00

MERRELL'S Digest of Materia Medica. Forming a Complete Pharmacopœia for the use of Physicians, Pharmacists and Students. By ALBERT MERRELL, M.D. Octavo. Half dark Calf, $4.00

MEYER. Ophthalmology. A Manual of Diseases of the Eye. By DR. EDOUARD MEYER, Prof. à L'École de la Faculté de Médicine de Paris, Chev. of the Legion of Honor, etc. Translated from the Third French Edition, with the assistance of the author, by A. FREEDLAND FERGUS, M.B., Assistant Surgeon Glasgow Eye Infirmary. With 270 Illustrations, and two Colored Plates prepared under the direction of DR. RICHARD LIEBREICH, M.R.C.S., Author of the "Atlas of Ophthalmoscopy." 8vo. Cloth, $4.50; Leather, $5.50

MILLER and LIZAR'S Alcohol and Tobacco. Alcohol. Its Place and Power. By JAMES MILLER, F.R.C.S.; and, Tobacco, Its Use and Abuse. By JOHN LIZARS, M.D. The two essays in one volume. Cloth, $1.00; Separate, each .50

MONEY. On Children. Treatment of Disease in Children, including the Outlines of Diagnosis and the Chief Pathological Differences between Children and Adults. By ANGEL MONEY, M.D., M.R.C.P., Asst. Physician to the Hospital for Sick Children, Great Ormond St., and to the Victoria Park Chest Hospital, London. *Practical Series. See Page 19.* 12mo. 560 pages. Cloth, $3.00

MORRIS. Compend of Gynæcology. By HENRY MORRIS, M.D., Demonstrator of Obstetrics, Jefferson Medical College, Phila., etc. *Being ? Quiz-Compend ? No. 7. Nearly Ready.*

MORTON on Refraction of the Eye. Its Diagnosis and the Correction of its Errors. With Chapter on Keratoscopy, and Test Types. By A. MORTON, M.B. Third Edition, Revised and Enlarged. Cloth, $1.00

MURRELL. Massage as a Mode of Treatment. By WM. MURRELL, M.D., M.R.C.P., Lecturer on Materia Medica and Therapeutics at Westminster Hospital, Examiner at University of Edinburgh, Physician to Royal Hospital for Diseases of the Chest. Third Edition. 12mo. Cloth, $1.50

MÜTER. Practical and Analytical Chemistry. By JOHN MÜTER, F.R.S., F.C.S., etc. Third Edition. Revised and Illustrated. Cloth, $2.00

OPHTHALMIC REVIEW. A Monthly Record of Ophthalmic Science. Published in London. *Sample Numbers, 25 cents.* Per annum, $3.00

OSGOOD. The Winter and Its Dangers. By HAMILTON OSGOOD, M.D. Cloth, .50

OVERMAN'S Practical Mineralogy, Assaying and Mining, with a Description of the Useful Minerals, etc. By FREDERICK OVERMAN, Mining Engineer. Eleventh Edition. 12mo. Cloth, $1.00

PACKARD'S Sea Air and Sea Bathing. By JOHN H. PACKARD, one of the Physicians to the Pennsylvania Hospital, Philadelphia. Cloth, .50

PAGE'S Injuries of the Spine and Spinal Cord, without apparent Lesion and Nervous Shock. In their Surgical and Medico-Legal Aspects. By HERBERT W. PAGE, M.D., F.R.C.S. Second Edition, Revised. Octavo. Cloth, $3.50

PAGET'S Lectures on Surgical Pathology. Delivered at the Royal College of Surgeons. By JAMES PAGET, F.R.S. Third Edition. Cloth, $7.00; Leather, $8.00

PARKES' Practical Hygiene. By EDWARD A. PARKES, M.D. The Seventh Revised and Enlarged Edition. With Many Illustrations. 8vo. Cloth, $4.50

PARRISH'S Alcoholic Inebriety. From a Medical Standpoint, with Illustrative Cases from the Clinical Records of the Author. By JOSEPH PARRISH, M.D., President of the Amer. Assoc. for Cure of Inebriates. Paper, .75; Cloth, $1.25

PARVIN'S Winckel's Diseases of Women (see Winckel-Parvin, page 24). 117 Illustrations. Cloth, $3.00; Leather, 3.50

PENNSYLVANIA Hospital Reports. Edited by a Committee of the Hospital Staff: J. M. DACOSTA, M.D., and WILLIAM HUNT. Containing Original Articles by the Staff. With many other Illustrations. Paper, .75; Cloth, $1.25

PHYSICIAN'S VISITING LIST. Published Annually. Thirty-eighth Year of its Publication.

SIZES AND PRICES.

For 25 Patients weekly.		Tucks, pocket and pencil, Gilt Edges, . .	$1.00
50 " "		" " " " " . .	1.25
75 " "		" " " " " . .	1.50
100 " "		" " " " " . .	2.00
50 " " 2 vols.	Jan. to June / July to Dec.	" " " . .	2.50
100 " " 2 vols.	Jan. to June / July to Dec.	" " " . .	3.00
INTERLEAVED EDITION.			
For 25 Patients weekly, interleaved, tucks, pocket, etc.,		" " . .	1.25
50 " " " " " " " " "		. .	1.50
50 " " 2 vols.	Jan. to June / July to Dec.	" " " " " . .	3.00

Perpetual Edition, without Dates and with Special Memorandum Pages.

For 25 Patients, interleaved, tucks, pocket and pencil, ... $1.25
50 " " " " " " 1.50

EXTRA Pencils will be sent, postpaid, for 25 cents per half dozen.

☞ This List combines the several essential qualities of strength, compactness, durability and convenience. A special circular, descriptive of contents and improvements, will be sent upon application..

PEREIRA'S Prescription Book. Containing Lists of Terms, Phrases, Contractions and Abbreviations used in Prescriptions, Explanatory Notes, Grammatical Construction of Prescriptions, Rules for the Pronunciation of Pharmaceutical Terms. By JONATHAN PEREIRA, M.D. Sixteenth Edition.
Cloth, $1.00; Leather, with tucks and pocket, $1.25

PHILLIPS' Materia Medica and Therapeutics. Vegetable Kingdom. Organic Compounds. Animal Kingdom. By CHAS. D. F. PHILLIPS, M.D., F.R.S., Edin., late Lecturer on Materia Medica and Therapeutics, Westminster Hospital, London. Second Edition (Complete). Enlarged and Revised. Cloth, $5.00

PIGGOTT on Copper Mining and Copper Ore. With a full Description of the Principal Copper Mines of the United States, the Art of Mining, etc. By A. SNOWDEN PIGGOTT. 12mo. Cloth, $1.00

PORTER'S Surgeon's Pocket-Book. By SURGEON-MAJOR J. H. PORTER, late Professor of Military Surgery in the Army Medical School, Netley, England. Revised, and partly Rewritten, by SURGEON-MAJOR C. H. GODWIN, of the Army Medical School (Netley, England). Third Edition. Small 12mo. Leather Covers, $2.25

POLYCLINIC, The. A Monthly Journal of Medicine and Surgery. Edited by HENRY LEFFMANN, M.D. 32 pages, monthly. Now in its 5th Volume. Royal 8vo. *Sample Numbers free.* Per annum, $1.00.

POWER, HOLMES, ANSTIE and BARNES (Drs.). Reports on the Progress of Medicine, Surgery, Physiology, Midwifery, Diseases of Women and Children, Materia Medica, Medical Jurisprudence, Ophthalmology, etc. Reported for the New Syndenham Society. 8vo. Paper, .75; Cloth, $1.25

POTTER. A Handbook of Materia Medica, Pharmacy and Therapeutics, including the Action of Medicines, Special Therapeutics, Pharmacology, etc. Including over 600 Prescriptions and Formulæ. By SAMUEL O. L. POTTER, M.A., M.D., Professor of the Practice of Medicine, Cooper Medical College, San Francisco; late A. A. Surgeon U. S. Army. Cloth, $3.00; Leather, $3.50

Speech and Its Defects. Considered Physiologically, Pathologically and Remedially; being the Lea Prize Thesis of Jefferson Medical College, 1882. Revised and Corrected. 12mo. Cloth, $1.00

Compend of Anatomy, including **Visceral Anatomy,** formerly published separately. Fourth Edition, Revised, and greatly Enlarged. With an Index and 117 Illustrations. *Being No. 1 ? Quiz-Compend ? Series.* Cloth, $1.00
Interleaved for taking Notes, $1.25

POTTER. Compend of Materia Medica, Therapeutics and Prescription Writing, arranged in accordance with the last Revision U. S. Pharmacopœia, with special reference to the Physiological Action of Drugs. Fifth Revised and Improved Edition, with Index. *Being No. 6 ? Quiz-Compend ? Series.* Cloth, $1.00. Interleaved for taking Notes, $1.25

PRINCE'S Plastic and Orthopædic Surgery. By DAVID PRINCE, M.D. Containing a Report on the Condition of, and Advance made in, Plastic and Orthopædic Surgery, etc. Numerous Illustrations. 8vo. Cloth, $4.50

PRITCHARD on the Ear. Handbook of Diseases of the Ear. By URBAN PRITCHARD, M.D., F.R.C.S., Professor of Aural Surgery, King's College, London, Aural Surgeon to King's College Hospital, Senior Surgeon to the Royal Ear Hospital, etc. 12mo. *Practical Series. See Page 19.* Cloth, $1.50

PROCTER'S Practical Pharmacy. Lectures on Practical Pharmacy. With 43 Engravings and 32 Lithographic Fac-simile Prescriptions. By BARNARD S. PROCTER. Second Edition. Cloth, $4.50

PYE. Surgical Handicraft. A Manual of Surgical Manipulations, Minor Surgery and other Matters connected with the work of Surgeons, Surgeons' Assistants, etc. By WALTER PYE, M.D., Surgeon to St. Mary's Hospital, London. 208 Illustrations. Cloth, $5.00

RADCLIFFE on Epilepsy, Pain, Paralysis, and other Disorders of the Nervous System. By CHARLES BLAND RADCLIFFE, M.D. Illus. Paper, .75 ; Cloth, $1.25

RALFE. Diseases of the Kidney and Urinary Derangements. By C. H. RALFE. Illustrated. 12mo. *Practical Series. See Page 19.* Cloth, $2.75

RANDALL & MORSE. Anatomy of the Ear. Photographic Illustrations of the Anatomy of the Human Ear, together with Pathological Conditions of the Drum Membrane, and Descriptive Text. By B. ALEX. RANDALL, A.M., M.D., and HENRY LEE MORSE, B.A., M.D. 25 Plates, comprising 75 Figures. Quarto. In Portfolio, *net*, 5.00

REESE'S Medical Jurisprudence and Toxicology. A Text-book for Medical and Legal Practitioners and Students. By JOHN J. REESE, M.D., Editor of Taylor's Jurisprudence, Professor of the Principles and Practice of Medical Jurisprudence, including Toxicology, in the University of Pennsylvania Medical Department. 2d. Ed. Enlarged. Crown Octavo. Cloth, $3.00 ; Leather, $3.50

REEVES. Bodily Deformities and their Treatment. A Handbook of Practical Orthopædics. By H. A. REEVES, M.D. *Practical Series. See Page 19.* Cloth, $2.25

REYNOLDS. Electricity. Lectures on the Clinical Uses of Electricity. By J. RUSSELL REYNOLDS, M.D., F.R.S. Second Edition. 12mo. Cloth, $1.00

RICHARDSON. Long Life, and How to Reach It. By J. G. RICHARDSON, Prof. of Hygiene, University of Penna. Cloth, .50

RICHARDSON'S Mechanical Dentistry. A Practical Treatise on Mechanical Dentistry. By JOSEPH RICHARDSON, D.D.S. Fifth Edition. Thoroughly Revised. With 569 Illustrations. 8vo. Cloth, $4.50 ; Leather, $5.50

RIGBY'S Obstetric Memoranda. 4th Ed. By ALFRED MEADOWS, M.D. 32mo. Cloth, .50

RINDFLEISCH'S General Pathology. A Handbook for Students and Physicians. By Prof. EDWARD RINDFLEISCH, of Wurzburg. Translated by WM. H. MERCUR, M.D., of Pittsburgh, Pa., Edited and Revised by JAMES TYSON, M.D., Professor of Morbid Anatomy and Pathology, University of Pennsylvania. Cloth, $2.00

RICHTER'S Inorganic Chemistry. A Text-book for Students. By Prof. VICTOR VON RICHTER, University of Breslau. Third American, from Fifth German Edition. Authorized Translation by EDGAR F. SMITH, M.A., PH.D., Prof. of Chemistry, University of Pennsylvania, Member of the Chemical Societies of Berlin and Paris. With 89 Illustrations and a Colored Plate of Spectra. 12mo. Cloth, $2.00

Organic Chemistry. A Text-book for Students. Translated from the Fourth German Ed., by Prof. Edgar F. Smith. Illus. Cloth, $3.00 ; Leather, $3.50

ROBERTS. Club-Foot. Clinical Lectures on Orthopædic Surgery, Nos. I and II. The Etiology, Morbid Anatomy, Varieties and Treatment of Club-Foot. By A. SYDNEY ROBERTS, M.D., Instructor in Orthopædic Surgery in the University of Pennsylvania, Surg. to the Univ. Hospital. Illustrated. 12mo. Cloth, .50

Bow-Legs. Clinical Lectures on Orthopædic Surgery. Nos. III and IV. Illustrated. 12mo. Cloth, .50

ROBERTS. Practice of Medicine. The Theory and Practice of Medicine. By FREDERICK ROBERTS, M.D., Professor of Therapeutics at University College, London. Seventh Edition, thoroughly revised and enlarged, with Illustrations. 8vo. Cloth, $5.50; Leather, $6.50

Materia Medica and Pharmacy. A Compend for Students. Cloth, $2.00

ROBERTS. Surgical Delusions and Follies. By JOHN B. ROBERTS, M.D., Professor of Anatomy and Surgery, in the Philadelphia Polyclinic. Paper, .25; Cloth, .50

The Human Brain. The Field and Limitation of the Operative Surgery of the Human Brain. Illustrated. 8vo. Cloth, $1.25

SANDERSON'S Physiological Laboratory. A Handbook of the Physiological Laboratory. Being Practical Exercises for Students in Physiology and Histology. By J. BURDON SANDERSON, M.D., E. KLEIN, M.D., MICHAEL FOSTER, M.D., F.R.S., and T. LAUDER BRUNTON, M.D. With over 350 Illustrations and Appropriate Letter-press Explanations and References. One Volume. Cloth, $5.00

SANSOM'S Diseases of the Heart. Valvular Disease of the Heart. By ARTHUR ERNEST SANSOM, M.D. Illustrated. 12mo. Cloth, $1.25

On Chloroform. Its Action and Administration. Paper, .75; Cloth, $1.25

SAVAGE. Atlas of the Female Pelvic Organs. The Surgery, Surgical Pathology and Surgical Anatomy of the Female Pelvic Organs. In a series of Plates taken from nature, with Commentaries, Notes and Cases. By HENRY SAVAGE, M.D., Lond., F.R.C.S. Fifth Edition. Revised and greatly extended. 17 Colored Plates, comprising many Figures. Quarto. Cloth, *net*, 12.00

SCANZONI. Sexual Organs of Women. A Practical Treatise on the Diseases of the Sexual Organs of Women. By F. W. VON SCANZONI, Prof. of Midwifery and Diseases of Females, University of Würzburg, etc. Edited by A. K. GARDNER, A.M., M.D. 60 Illustrations. Fourth Edition. Octavo. Cloth, $4.00

SCHULTZE'S Obstetrical Plates. Obstetrical Diagrams. Life Size. By Prof. B. S. SCHULTZE, M.D., of Berlin. Twenty in the Set. Colored. In Sheets, $15.00; Mounted on Rollers, $25.00

SMITH'S Wasting Diseases of Infants and Children. By EUSTACE SMITH, M.D., F.R.C.P., Physician to the East London Children's Hospital. Fifth London Edition, Enlarged. 8vo. Cloth, $3.00

Clinical Studies of Diseases in Children. Second Edition, Revised. 8vo. Cloth, $2.50

SMITH. Abdominal Surgery. Being a Systematic Description of all the Principal Operations. By J. GREIG SMITH, M.A., F.R.S.E., Surg. to British Royal Infirmary, Fellow Royal Med. Chir. Soc., etc. With 45 Engravings. 8vo. New Edition, Enlarged. $7.00

SMITH (TYLER). Lectures on Obstetrics. Delivered at St. Mary's Hospital. With an Introductory Lecture on the History and Art of Midwifery, and Copious Annotations. By A. K. GARDNER, A.M., M.D. 233 Illus. 3d Ed. 8vo. Cloth, $4.00

SMYTHE'S Medical Heresies. Historically Considered. By GONZALVO C. SMYTHE, A.M., M.D. 12mo. Cloth, $1.25

STAMMER. Chemical Problems, with Explanations and Answers. By KARL STAMMER. Translated from the 2d German Edition, by Prof. W. S. HOSKINSON, A.M., Wittenberg College, Springfield, Ohio. 12mo. Cloth, .75

STARR. The Digestive Organs in Childhood. The Diseases of the Digestive Organs in Infancy and Childhood. With Chapters on the Investigation of Disease and the Management of Children. By LOUIS STARR, M.D., Clinical Prof. of Diseases of Children in the Hospital of the University of Penn'a; Physician to the Children's Hospital, Phila. 8vo. Cut or uncut edges. Cloth, $2.50

STARR. The Hygiene of the Nursery. With Twenty-one Illustrations. $1.50

STARR and WALKER. Physiological Action of Medicines. Prepared for the use of Students of the Medical Department, University of Penna. By LOUIS STARR, M.D., J. B. WALKER, M.D. and W. M. POWELL, M.D. Third Edition. Enlarged. 32mo. Cloth, .75

STEWART'S Compend of Pharmacy. Based upon "Remington's Text-Book of Pharmacy." By F. E. STEWART, M.D., PH.G., Quiz Master in Chem. and Theoretical Pharmacy, Phila. College of Pharmacy; Demonstrator and Lect. in Pharmacology, Medico-Chirurgical College, and in Woman's Medical College. 2d. Ed. *? Quiz-Compend ? Series.* Cloth, $1.00; Interleaved for the addition of notes, $1.25

STIRLING. Outlines of Practical Physiology. Including Chemical and Experimental Physiology, with Special Reference to Practical Medicine. By W. STIRLING, M.D., SC.D., Prof. of Phys., Owens College, Victoria University, Manchester. Examiner in Honor's School of Science, Oxford, England. 142 Illustrations. 309 pages. Cloth, $2.25

STOCKEN'S Dental Materia Medica. Dental Materia Medica and Therapeutics, with Pharmacopœia. By JAMES STOCKEN, D.D.S. Third Edition. Cloth, $2.50

SUTTON'S Volumetric Analysis. A Systematic Handbook for the Quantitative Estimation of Chemical Substances by Measure, Applied to Liquids, Solids and Gases. By FRANCIS SUTTON, F.C.S. Fifth Edition, Revised and Enlarged, with Illustrations. 8vo. Cloth, $4.50

SUTTON. Pathology. An Introduction to General Pathology, founded on three lectures delivered at the Royal College of Surgeons of England, 1886. By JOHN BLAND SUTTON, F.R.C.S., Lecturer on Pathology, Royal College of Surgeons; Assistant Surgeon and Demonstrator of Anatomy, Middlesex Hospital, London. 149 Illustrations. Cloth, $4.50

Ligaments. Their Nature and Morphology. Illustrated. 12mo. Cloth, 1.25

SWAIN. Surgical Emergencies, together with the Emergencies Attendant on Parturition and the Treatment of Poisoning. A Manual for the Use of General Practitioners. By W. F. SWAIN, F.R.C.S. Fourth Edition. Illustrated. 1.50

SWAYNE'S Obstetric Aphorisms, for the Use of Students commencing Midwifery Practice. By JOSEPH G. SWAYNE, M.D. Eighth Edition. Illus. Cloth, $1.25

TAFT'S Operative Dentistry. A Practical Treatise on Operative Dentistry. By JONATHAN TAFT, D.D.S. Fourth Revised and Enlarged Edition. Over 100 Illustrations. 8vo. Cloth, $4.25; Leather, $5.00

Index of Dental Periodical Literature. 8vo. Cloth, $2.00

TALBOT. Irregularities of the Teeth, and Their Treatment. By EUGENE S. TALBOT, M.D., Professor of Dental Surgery Woman's Medical College, and Lecturer on Dental Pathology in Rush Medical College, Chicago. Octavo. 150 Illustrations. Cloth, $2.00

TANNER'S Index of Diseases and their Treatment. By THOS. HAWKES TANNER, M.D., F.R.C.P. Second Edition, Revised and Enlarged. By W. H. BROADBENT, M.D. With Additions. Appendix of Formulæ, etc. 8vo. Cloth, $3.00

Memoranda of Poisons and their Antidotes and Tests. Sixth American, from the Last London Edition. Revised by HENRY LEFFMANN, M.D., Professor of Chemistry in Pennsylvania College of Dental Surgery and in the Philadelphia Polyclinic. Cloth, .75

TECHNOLOGICAL SERIES. The Brewer, Distiller and Wine Manufacturer. A Handbook for all Interested in the Manufacture and Trade of Alcohol and Its Compounds. Edited by JOHN GARDNER, F.C.S. Illustrated. Cloth, $1.75

Bleaching, Dyeing, and Calico Printing. With Formulæ. Illustrated. $1.75

Acetic Acid, Vinegar, Ammonia and Alum. Illustrated. Cloth, $1.75

Oils and Varnishes. Edited by JAMES CAMERON, F.I.C. Illustrated. $2.50

Soap and Candles. Edited by JAMES CAMERON. $2.25

TEMPERATURE Charts for Recording Temperature, Respiration, Pulse, Day of Disease, Date, Age, Sex, Occupation, Name, etc. Put up in pads; each .50

THOMPSON. Lithotomy and Lithotrity. Practical Lithotomy and Lithotrity; or an Inquiry into the best Modes of Removing Stone from the Bladder. By Sir HENRY THOMPSON, F.R.C.S., Emeritus Professor of Clinical Surgery in University College. Third Edition. With 87 Engravings. 8vo. Cloth, $3.50

Urinary Organs. Diseases of the Urinary Organs. 7th London Ed. Cloth, $1.25

On the Prostate. Diseases of the Prostate. Their Pathology and Treatment. Sixth London Edition. 8vo. Illustrated. Cloth, $2.00

Calculous Diseases. The Preventive Treatment of Calculous Disease, and the Use of Solvent Remedies. Second Edition. 16mo. Cloth, $1.00

Surgery of the Urinary Organs. Some Important Points connected with the Surgery of the Urinary Organs. Illus. Paper, .75; Cloth, $1.25

TIDY. Modern Chemistry, Inorganic and Organic. A Handbook for the Use of Students. By CHAS. MEYMOTT TIDY, F.R.C., Prof. of Chemistry and Medical Jurisprudence and Public Health at London Hospital; Medical Officer of Health and Public Analyst of the City of London, etc. 8vo. Second Edition. Revised and Enlarged. Cloth, $5.50

TILT'S Change of Life in Women, in Health and Disease. A Practical Treatise on the Diseases incidental to Women at the Decline of Life. By EDWARD JOHN TILT, M.D. Fourth London Edition. 8vo. Paper cover, .75; Cloth, $1.25

TOMES' Dental Anatomy. A Manual of Dental Anatomy, Human and Comparative. By C. S. TOMES, D.D.S. 191 Illustrations. 3d Ed. 12mo. *In Press.*

Dental Surgery. A System of Dental Surgery. By JOHN TOMES, F.R.S. Fourth Edition, Revised and Enlarged. By C. S. TOMES, D.D.S. With 292 Illustrations. 12mo. 772 pages. Cloth, $5.00

TRANSACTIONS of the College of Physicians of Philadelphia. Third Series. Vols. I, II, III, IV, V, Cloth, each, $2.50. VI, VII, Cloth, each, $3.50. Vol. VIII, 1886, Cloth, $3.75.

TRANSACTIONS American Surgical Association. Illustrated. Royal 8vo. Price of Vol. I, Cloth, $3.50; Vol. II, Cloth, $4.00; Vol. III, Cloth, $3.50 Vol. IV, Cloth, $3.00. Vol. V, Cloth, $4.25.

TRIMBLE. Practical and Analytical Chemistry. Being a complete course in Chemical Analysis. By HENRY TRIMBLE, PH.G., Professor of Analytical Chemistry in the Philadelphia College of Pharmacy. Second Edition. Enlarged. Illustrated. 8vo. Cloth, $1.50

TURNBULL'S Artificial Anæsthesia. The Advantages and Accidents of Artificial Anæsthesia; Its Employment in the Treatment of Disease; Modes of Administration; Considering their Relative Risks; Tests of Purity; Treatment of Asphyxia; Spasms of the Glottis; Syncope, etc. By LAURENCE TURNBULL, M.D., PH. G., Aural Surgeon to Jefferson College Hospital, etc. Second Edition, Revised and Enlarged. With 27 Illustrations of Various Forms of Inhalers, etc., and an appendix of over 70 pages, containing a full account of the new local Anæsthetic, Hydrochlorate of Cocaine. 12mo. Cloth, $1.50

Hydrochlorate of Cocaine. 12mo. Paper, .50

TUSON. Veterinary Pharmacopœia. Including the Outlines of Materia Medica and Therapeutics. For the Use of Students and Practitioners of Veterinary Medicine. By RICHARD V. TUSON, F.C.S. Third Edition. 12mo. Cloth, $2.50

TYSON. Bright's Disease and Diabetes. With Especial Reference to Pathology and Therapeutics. By JAMES TYSON, M.D., Professor of Pathology and Morbid Anatomy in the University of Pennsylvania. Including a Section on Retinitis in Bright's Disease. By WM. F. NORRIS, M.D., Clin. Prof. of Ophthalmology, in Univ. of Penna. With Colored Plates and many Wood Engravings. 8vo. Cloth, $3.50

Guide to the Examination of Urine. Sixth Edition. For the Use of Physicians and Students. With Colored Plates and Numerous Illustrations Engraved on Wood. Sixth Edition. Enlarged and Revised. 12mo. 250 pages. Cloth, $1.50

Cell Doctrine. Its History and Present State. With a Copious Bibliography of the subject. Illustrated by a Colored Plate and Wood Cuts. Second Edition. 8vo. Cloth, $2.00

TYSON. Rindfleisch's Pathology. Edited by Prof. TYSON. General Pathology; a Handbook for Students and Physicians. By Prof. EDWARD RINDFLEISCH, of Wurzburg. Translated by WM. H. MERCUR, M.D. Edited and Revised by JAMES TYSON, M.D., Professor of Morbid Anatomy and Pathology, University of Pennsylvania. Cloth, $2.00

VALENTIN'S Qualitative Analysis. A Course of Qualitative Chemical Analysis. By WM. G. VALENTIN, F.C.S. Sixth Edition. Illustrated. Octavo. Cloth, $3.00

VAN HARLINGEN on Skin Diseases. A Practical Manual of Diagnosis and Treatment. By ARTHUR VAN HARLINGEN, M.D., Professor of Diseases of the Skin in the Philadelphia Polyclinic; Consulting Physician to the Philadelphia Dispensary for Skin Diseases. Second Edition. Revised and Enlarged. With Formulæ. New Illustrations. *Nearly Ready.*

VAN NÜYS on The Urine. Chemical Analysis of Healthy and Diseased Urine, Qualitative and Quantitative. By T. C. VAN NÜYS, Professor of Chemistry Indiana University. 39 Illustrations. Octavo. Cloth, $2.00

VIRCHOW'S Post-mortem Examinations. A Description and Explanation of the Method of Performing them in the Dead House of the Berlin Charité Hospital, with especial reference to Medico-legal Practice. By Prof. VIRCHOW. Translated by Dr. T. P. SMITH. Third Edition, with Additions and New Plates. 12mo. *Series of Medical Briefs, No.* 1. Cloth, $1.00

Cellular Pathology, as based upon Physiological and Pathological Histology. 20 Lectures delivered at the Pathological Institute of Berlin. Translated from the 2d Ed. by F. CHANCE, M.D. 134 Illus. 8th Am. Ed. Cloth, $4.00

WALSHAM. Manual of Practical Surgery. For Students and Physicians. By WM. J. WALSHAM, M.D., F.R.C.S., Asst. Surg. to, and Dem. of Practical Surg. in, St. Bartholomew's Hospital, Surg. to Metropolitan Free Hospital, London. With 236 Engravings. 656 pages. *New Series of Manuals.* Cloth, $3.00; Leather, $3.50

WARING. Practical Therapeutics. A Manual for Physicians and Students. By Edward J. Waring, M.D. Fourth Edition. Revised, Rewritten and Rearranged by DUDLEY W. BUXTON, M.D., Assistant to the Professor of Medicine, University College, London. Crown Octavo. Cloth, $3.00; Leather, $3.50

WARNER. Case Taking. A Manual of Clinical Medicine and Case Taking. By FRANCIS WARNER, M.D. Second Edition. Cloth, $1.75

WATSON on Amputations of the Extremities and Their Complications. By B. A. WATSON, A.M., M.D., Surgeon to the Jersey City Charity Hospital and to Christ's Hospital, Jersey City, N. J.; Member of the American Surgical Association. With over 250 Wood Engravings and two Full-page Colored Plates. Octavo. 770 pages. Cloth, $5.50

WATTS' Inorganic Chemistry. A Manual of Chemistry, Physical and Inorganic. (Being the 13th Edition of FOWNE'S PHYSICAL AND INORGANIC CHEMISTRY.) By HENRY WATTS, B.A., F.R.S., Editor of the Journal of the Chemical Society; Author of "A Dictionary of Chemistry," etc. With Colored Plate of Spectra and other Illustrations. 12mo. 595 pages. Cloth, $2.25

Organic Chemistry. Second Edition. By WM. A. TILDEN, D.SC., F.R.S. (Being the 13th Edition of FOWNE'S ORGANIC CHEMISTRY.) Illustrated. 12mo. Cloth, $2.25

WELCH'S Enteric Fever. Its Prevalence and Modifications; Ætiology, Pathology and Treatment. By FRANCIS H. WELCH, F.R.C.S. 8vo. Cloth, $2.00

WHITE. The Mouth and Teeth. By J. W. WHITE, M.D., D.D.S. Editor of the Dental Cosmos. Illustrated. Cloth, .50

WICKES' Sepulture. Its History, Methods and Sanitary Requisites. By STEPHEN WICKES, A.M., M.D. Octavo. Cloth, $1.50

WILLIAMS. Pulmonary Consumption. Its Etiology, Pathology and Treatment, with an Analysis of 1000 Cases to Exemplify its Duration and Modes of Arrest. By C. J. B. WILLIAMS, M.D. Second Edition. Enlarged and Rewritten. By C. THEODORE WILLIAMS, M.D. With 4 Colored Plates and other Illustrations. Octavo. Cloth, 5.00

WILSON. The Summer and Its Diseases. By JAMES C. WILSON, M.D. Cloth, .50

WILSON'S Text-Book of Domestic Hygiene and Sanitary Information. A Guide to Personal and Domestic Hygiene. By GEORGE WILSON, M.D., Medical Officer of Health. Edited by JOS. G. RICHARDSON, M.D., Professor of Hygiene at the University of Pennsylvania. Cloth, $1.00

Handbook of Hygiene and Sanitary Science. With Illustrations. Sixth Edition, Revised and Enlarged. 8vo. Cloth, $2.75

WINCKEL-PARVIN. Diseases of Women. By Dr. F. WINCKEL, Professor of Gynæcology, and Director of the Royal University Clinic for Women, in Munich. Translated by special authority of Author and Publisher, by Dr. J. H. WILLIAMSON, Resident Physician of Allegheny General Hospital, Allegheny, Pa., under the supervision of, and with an Introduction by, THEOPHILUS PARVIN, M.D., Professor of Obstetrics and Diseases of Women and Children in Jefferson Medical College, Philadelphia. With 132 Engravings on Wood, most of which are entirely new. Demi-octavo. Cloth, $3.00; Leather, $3.50

WOAKES. Post-Nasal Catarrh and Diseases of the Nose, causing Deafness. By EDWARD WOAKES, M.D., Senior Aural Surgeon to the London Hospital for Diseases of the Throat and Chest. 26 Illustrations. Cloth, $1.50

Nasal Polypus, with Neuralgia, Hay Fever and Asthma in Relation to Ethmoiditis. 12mo. Cloth, $1.25

On Deafness, Giddiness and Noises in the Head, or the Naso-Pharyngeal aspect of Ear Disease. Third Edition. Illustrated. *In Press.*

WOLFF. Manual of Applied Medical Chemistry for Students and Practitioners of Medicine. By LAWRENCE WOLFF, M.D., Demonstrator of Chemistry in Jefferson Medical College, Philadelphia. Cloth, $1.00

WOOD. Brain Work and Overwork. By Prof. H. C. WOOD, Clinical Professor of Nervous Diseases, University of Pennsylvania. 12mo. Cloth, .50

WOODMAN and TIDY. Medical Jurisprudence. Forensic Medicine and Toxicology. By W. BATHURST WOODMAN, M.D., Physician to the London Hospital, and CHARLES MEYMOTT TIDY, F.C.S., Professor of Chemistry and Medical Jurisprudence at the London Hospital. With Chromo-lithographic Plates, representing the Appearance of the Stomach in Poisoning by Arsenic, Corrosive Sublimate, Nitric Acid, Oxalic Acid; the Spectra of Blood and the Microscopic Appearance of Human and other Hairs; and 116 other Illustrations. Large Octavo. *Sold by Subscription.* Cloth, $7.50; Leather, $8.50

WRIGHT on Headaches; their Causes, Nature and Treatment. By HENRY G. WRIGHT, M.D. 12mo. Cloth, .50

WYTHE on the Microscope. A Manual of Microscopy and Compendium of the Microscopic Sciences, Micro-mineralogy, Biology, Histology and Practical Medicine, with Index and Glossary and the genera of microscopic plants. By JOSEPH H. WYTHE, A.M., M.D. Fourth Edition. 252 Illus. Cloth, $3.00

Dose and Symptom Book. The Physician's Pocket Dose and Symptom Book. Containing the Doses and Uses of all the Principal Articles of the Materia Medica, and Original Preparations. 17th Edition, Revised and Rewritten *Just Ready.* Cloth, $1.00; Leather, with Tucks and Pocket, $1.25

YEO'S Manual of Physiology. Third Edition. A Text-book for Students of Medicine. By GERALD F. YEO., M.D. F.R.C.S., Professor of Physiology in King's College, London. Third Edition; revised and enlarged by the author. With New Illustrations. 321 carefully printed Wood Engravings. A Glossary and Complete Index. Crown Octavo. *Being No. 4, New Series of Manuals.* Cloth, $3.00; Leather, $3.50

"After a careful examination of this Manual of Physiology, I can truthfully say that it is a most valuable addition to the list of text-books upon this subject. That it should and will receive a welcome from both students and teachers there can be no doubt. The author presents his subject in a manner that is clear, concise and logical. Each section has had a careful revision, and reveals the author's familiarity with the scope and tendencies of modern physiology."—*A. P. Brubaker, M.D., Demonstrator of Physiology at Jefferson Medical College, Philadelphia.*

JUST READY. A TEXT-BOOK OF

DISEASES OF THE EYE.

BY DR. EDOUARD MEYER,

Prof. à L'École Pratique de la Faculté de Médecine de Paris; Chevalier of the Legion of Honor,

AUTHORIZED TRANSLATION BY

FREELAND FERGUS, M. B., Assistant Surgeon, Glasgow Eye Infirmary.

COLORED PLATES PRINTED UNDER THE DIRECTION OF

DR. RICHARD LIEBREICH, M. R. C. S., Author of the "Atlas of Ophthalmoscopy."

WITH COLORED PLATES AND 267 ENGRAVINGS ON WOO

Octavo. 650 Pages. Cloth, $4.50; Leather, $5.50.

SYNOPSIS OF CONTENTS.—Diagnosis and Treatment of Ocular Affections. Diseases of the Conj tiva. Diseases of the Cornea and Sclerotic. Iris—Ciliary Body—Choroid. Glaucoma. Diseases of Optic Nerve and Retina. Amblyopia and Amaurosis. Diseases of the Vitreous Body. Diseases of Crystalline Lens. Refraction and Accommodation. The Muscles of the Eye. Diseases of the Eye Diseases of the Lachrymal Passages. Diseases of the Orbit. Table of Dioptries. Index.

Forming a complete systematic Manual of Ophthalmology. The translat and editing have been done with the assista of the author. The illustrations, which will found of great help in diagnosis, have been ca fully engraved; the colored plates, being duced from Liebreich's Atlas of Ophthalmolo and printed under the direction of Dr. Liebrei are accurate and faithful representations of th subjects.

FIG. 27.—PTERYGIUM.

(Attention is called to the help in diagnosis of a cut of this character. It is followed by three engravings showing the operation for Pterygium.)

TREATMENT and DIAGNOSIS receive full sha of attention. Refraction and accommodati occupy a section of over sixty pages, bei handled in a practical, concise way that w commend itself specially to students and phys cians who have given the subject but little attention. The chapters describing t subject of general diagnosis and the proper instruments to be used, are thoroug and well illustrated.

Dr. Swan M. Burnett, reviewing the book in *The Archives of Ophthalmology*, says: "The cause of its popularity is far to seek. It is clear, concise, conservative and eminently practical."

This book has gone through three French and four German Edition has been translated into Italian, Spanish, Polish, Russian, Japanese this, the English Edition, making the eighth language in which it ha been published.

P. BLAKISTON, SON & Co., Publishers, 1012 Walnut Street, Philadelphia

[redacted]